PRIZE ESSAY.

AN EXPERIMENTAL ESSAY

ON THE

PHYSIOLOGY OF THE BLOOD,

FOR WHICH

A GOLD MEDAL

WAS AWARDED BY

THE MEDICAL FACULTY OF THE UNIVERSITY OF EDINBURGH.

By CHARLES MAITLAND, M.D.
BRIGHTON.

EDINBURGH:
JOHN CARFRAE AND SON,
AND LONGMAN, ORME, BROWN, GREEN & LONGMAN, LONDON.

MDCCCXXXVIII.

pp i-ii (half-title)
wanting

TO

TWEEDY JOHN TODD, M.D.

OF BRIGHTON,

AS A SMALL TOKEN OF ESTEEM

FOR HIS PRIVATE AND PROFESSIONAL CHARACTER,

THE FOLLOWING PAGES

ARE INSCRIBED

BY HIS SINCERE FRIEND,

THE AUTHOR.

PREFACE.

The following Essay contains some researches into the Physiology and Organic Relations of the Blood in a healthy state, undertaken by the author with a view to the subsequent examination of that fluid in its morbid conditions. The time and opportunities requisite for the pursuit of this latter department of the subject seem to place it beyond the reach of the student, and assign it to the interval (often sufficiently long) between the termination of academic studies, and the full exercise of the privileges thereby acquired.

The field is as promising as it is imperfectly examined: for although we are seldom able to deduce practical rules directly from ultimate facts, the knowledge of such facts is valuable, in enabling us to decide between the claims of contending systems of practical medicine.

CONTENTS.

Introductory Remarks.

CHAPTER I.

Mechanical Constitution of the Blood.

CHAPTER II.

Chemical Constitution of the Blood.

CHAPTER III.

Effects of Respiration on the Blood.

CHAPTER IV.

On the Vitality of the Blood.

CHAPTER V.

Organic Relations of the Blood.

INTRODUCTORY REMARKS.

Could we take possession of the kingdoms of Nature, so as to distribute her dominions among the followers of Science, we should scarcely find it possible to ensure a more universal system of research, or a more equal division of labour, than have resulted from each one following the department best suited to his natural inclination.

It might have been anticipated, that the subjects of most general interest would have attracted a larger share of attention than those which, from various reasons, we are inclined to pass by unnoticed; but the most cursory review of the history of science is sufficient to convince us of the contrary. We find a Bell engaged for years in ascertaining the functions of a nerve, while a Müller is as sedulously employed in measuring a microscopic cavity; nor has the repulsiveness of one object, nor the personal inconvenience incurred in following another, deterred a Prout or a Stark from his favourite pursuit.

As far as the progress of science is concerned, it matters little to what department any individual may devote his attention, but on his own account he will find it most profitable to undertake such as may furnish him with important and practical knowledge. No apology can therefore be needed from the student of medicine for attempting a subject of such interest as the blood, unless it be on the ground of incompetency, or of a degree of presumption, in engaging in so arduous an occupation. But this is a field so abundantly fertile, that the

multitude of labourers engaged have as yet very imperfectly succeeded in gathering in the harvest; and the ears that drop from their overflowing grasp will fully reward the toil of the humble gleaner.

It has been observed by a modern author, that the researches of science, where successful in their object, have frequently served to confirm many popular opinions, which, at an earlier period they seemed to contradict. On reviewing the history of medicine, this remark will be found applicable on several occasions, and perhaps on none more so, than when we endeavour to trace the degree of importance attached at different periods to the fluids of the animal economy, both in health and disease.

From the earliest times, it has been the custom of nations to localize diseases, and even the principle of life, in the fluid constituents of our system; with how much of truth or of error, we shall have occasion to examine presently. Among these, they gave pre-eminence to the blood, which, as well as the most generally diffused, is certainly the most important. Nor were their pathological notions inconsistent with the *rationale* of their therapeutics, for they looked to the morbid alterations of these fluids, whether real or imaginary, as affording the best indications of cure. And though little progress could be expected in this branch of knowledge, without the assistance of morbid anatomy and animal chemistry, yet did the ancient philosophers succeed in ascertaining some important facts, which, at this distance of time, appear the more remarkable, from the mass of conjecture by which they are surrounded.

As sound views of pathology must be based upon correct physiological notions, so do we find the converse equally true; and are enabled to gather pretty accurately the amount of physiological knowledge enjoyed by the earlier physicians, from the theories which they employed in accounting for the symptoms of disease. For this reason, it will be instructive to glance briefly at the history of the humoral pathology during the few last centuries, by which means we may form an estimate of its true value or worthlessness, and be the less liable to reject truth because mixed with error, and exposed to

the ridicule of those whose judgment we are inclined to respect.

The humoral pathology, under which term are included all modifications of the idea that the seats of disease are to be found principally in the fluids, is the general belief of antiquity, the classic ground of medical literature. All poetical allusions to disease, as well as the expressions generally employed by us in conversation, are couched in terms recognizing the truth of this supposition. The schools of Galen, Paracelsus, and others, however they differed among themselves, were united upon this point ; and it is comparatively an innovation to look for the explanation of morbid phenomena in the brain and nervous system.

Of the successive theories of medicine founded upon these views, the latest and most complete was that of the great Boerhaave, who proceeded to speak with some precision of what he considered to be the morbid states of the fluids ; as the alkalinity or acidity of the blood, *phlegma calidum*, *glutinosum spontaneum*, &c. But the doctrines of Cullen were destined to sweep away the entire fabric of so many centuries, and the humoral pathology was abandoned by all, while its late supporters made no effort to save from the ruins the valuable mass of facts which were overwhelmed in the rubbish.

The progress of science, and general adoption of the inductive philosophy, contributed much to the downfall of the ancient system, which occurred about the middle of the last century; and the subsequent advance of organic chemistry, together with more extended researches in the collateral branches, have since tended to shew that its opponents have gone somewhat to the opposite extreme, bestowing exclusive attention on the solids of the body, to the neglect of its fluid constituents. Indeed, the most recent observations seem to justify the conclusion, that in many cases the fluids are primarily affected, and that the expressions, *bad*, or *impoverished* blood, *rich*, or *inflammatory* blood, are much more correct than has of late been supposed.

Whether a pathology so far humoral will ever be borne out by facts, as that the examination of a small portion of the

blood shall become as regular an instrument of diagnosis as the appearance of the tongue and the varieties of the pulse are at present, and whether the effects of chemical remedies acting on the fluids will ever be reduced to the certainty with which the action of stimulants and sedatives is now anticipated, are questions which time alone can answer; meanwhile, let us adhere to facts, neither hastily adopting what appears plausible, nor rejecting what may seem in the present state of our knowledge unlikely; by such means we may best preserve the profession to which we belong, from the hypothetical conceits and acrimonious controversies which have too often lowered it in the general estimation.

At a time when solidism possessed absolute sway in France, Bichat thus expressed himself,—"The humoral pathology has no doubt been carried too far, but it is founded on truth, and in a great many cases we must allow that all should be referred to the morbid humours." And if we consider the subject with a little attention, we shall find cause for wonder that the fluids, especially the blood, have ever been so far removed from their natural connexion with the solids, as to form the basis of a separate system of medicine. It is partly owing, however, to the circumstance, that we are apt to form our ideas of the blood from what we observe in it when in small quantity, and removed from its containing vessels: let us consider it as a whole, *in situ*, and engaged in the performance of its complex functions.

If we think of the blood as a mere fluid, propelled through tubes by vital powers, acted on by containing vessels, but itself unable to react upon the parts which surround it, we misconceive of its nature, and throw ourselves open to serious mistakes in practice. Blood is a structure, circulating through, and continuous with, all structures; and representing their wants where alone they can be supplied, it returns to the extremities, pervades every part, and diffuses that principle which has been entrusted to it in the lungs.

There is a difficulty to be overcome here, which I do not recollect as alluded to by any writer on the subject; the structures in the interior of our frame must have access to oxygen,

and as they cannot be brought into contact with the atmosphere, some means must be devised for conveying oxygen to them. It is clear that the blood does not need the vast amount of that gas absorbed by it, for it is as constantly deprived of it in the extreme capillaries, and as the circulation is much slower in the veins than in the arteries, the blood must exist in the dark form during the greater part of our lives. We are, therefore, at no loss to ascertain by what means this element is furnished to the solids, and how they must suffer if this function be materially deranged. In this view, respiration is a general function of the system, deputed to the blood as by proxy, and performed in the pulmonary tissue; and the globules of the blood may be considered as representatives of the solids, by which these latter maintain their connexion with the seat of such important agencies.

The blood in the larger vessels seems to have little connexion with the parts in contact with it; but in the capillaries, its relation to the containing structures is most intimate. When viewed in this situation with a microscope, Professor Schultz has compared the blood to a whirlpool, from which particles are continually detached to be lost in the solid substance, while others are quitting this latter, to be merged in the torrent. "At their point of contact," observes M. Andral, "the blood assumes the nature of the solid, and becomes organized; so that its vitality can be no longer doubted." The truth of these observations of Schultz has been questioned, but on other grounds we have good reason for concluding, that the blood is in part reduced from the solids, and goes to be directly added to their mass. From this we are prepared to find that the morbid states of either division of our system may be mutually productive of each other; so much so, as often to prevent us from deciding in which of the two they take their origin. Since, therefore, the blood intervenes between the processes of digestion and nutrition, as well as between those of absorption and secretion, we might suppose from direct reasoning, that the proximate causes of disease in the nutritive and secrenent systems might be shared between the organs concerned in those operations, and the fluid upon which they

act. The progress of organic chemistry is daily accumulating proofs of the truth of this view of the matter; and it is now very generally admitted that any system of medicine is defective which refuses to admit either solids or fluids as the seats of morbid change. In making these remarks, it is not my intention to follow up the pathological conditions of the blood, or to trace the symptoms which characterize them; on the present occasion, it is proposed to confine our attention to the physiology of this fluid, in the belief, that by studying it in health, we gain an important step towards detecting its alterations in disease.

Together with the mechanical and chemical constitution of the blood, will be considered its origin, changes, and destination, as well as what is known respecting the alterations to which it is liable from the circumstances of age, sex, and temperament. The comparative physiology of the blood will be so far attended to, as may serve to illustrate general principles, or to ascertain facts which are not easily demonstrated in the human subject.

CHAPTER I.

MECHANICAL CONSTITUTION OF THE BLOOD.

In the higher classes of animals, the red colour and general consistency of the blood, together with its tendency to spontaneous coagulation, serve at once to distinguish it from all other substances, whether natural or artificial. In the lower classes, indeed, it is often difficult to determine which is their blood; a whitish, yellow, or even a blue tint taking the place of red, and even in man its appearance is much altered in many diseases.

The blood of mammalia is of a florid red colour in the arteries, and a dark Modena hue in the veins. Its taste is somewhat saline, its reaction weakly alkaline; its odour peculiar, and it communicates an unctuous sensation to the finger. Its temperature, while flowing in its vessels, ranges during health from 100·6° F. to 101·75°; and the experiments instituted to determine its variation in different countries, have at present only afforded unsatisfactory results.

A knowledge of the exact specific gravity of healthy blood is important, its morbid variations being easily compared with it. By the latest experiments it is fixed at between 1·052 and 1·057. It is difficult to determine the amount of this fluid contained in our bodies; in the adult it has been estimated as ranging from eight to thirty pounds.

The mechanical composition of the blood can only be ascertained by means of the microscope; when examined with this instrument, it is found to be composed of two parts; numerous red globules of exceedingly small dimensions, and a nearly

colourless fluid in which they are suspended. This interesting fact has not failed to call forth the industry of numerous and accurate observers, by whose joint labours we are enabled to describe with some certainty the dimensions and figure of these bodies, whose discovery was hailed with such enthusiasm, and commented upon with so much imagination. The first accounts are, as might be expected, very little accordant; and among other fanciful notions, it was stated in allusion to the supposed arrangement of the fibrin and colouring matter, that "the wheels of life run upon iron axles."

In man and the other mammalia, these globules take the form of flattened circular discs, but in the remaining classes of vertebrated animals, including birds, reptiles, and fishes, they are elliptical.

On descending still lower in the scale of existence, we find the globules of the invertebrate returning to the circular form. These bodies are not homogeneous,—they consist of a central colourless nucleus composed of fibrin, and a red envelope, both of which will be fully described presently. While invested with this covering, the nuclei shew no tendency to cohere, but when deprived of it by the action of weak acetic acid, they rapidly form a solid mass. After much difference of opinion, the diameter of a blood globule has been fixed at about $\frac{1}{4000}$ of an English inch, or according to Professor Müller, at ·00029 inch. It is remarkable that the size of the globule bears no relation to that of the animal from which it is taken; in the salamander, for example, the long diameter of the ellipse is ·001132, and the shorter ·000704, while in the dog and goat the diameter of the circle is ·000104. In the oyster and crab they vary considerably in the same drop of blood. These facts throw some light upon the experiments made upon the transfusion of blood, in which it was found that animals suffered with difficulty the transfusion of blood from an individual whose blood-globules differed in size or figure materially from their own. Thus the blood of mammalia proves instantly and certainly fatal to birds—pigeons were killed by a few drops of the blood of a sheep.

Notwithstanding our knowledge of the size and form of

these globules, the subject of transfusion presents difficulties which at present are beyond our power to solve. Dr. Bischoff found that when he removed the fibrin from blood by stirring, and raised the fluid to its proper temperature, no such injurious effects were produced. Dr. Baly witnessed the performance of these experiments at Heidelberg, and says that they were so frequently repeated, that there could be no fallacy in the result. The conclusion drawn by these gentlemen is, that the fibrin is in some way connected with the poisonous quality of dissimilar blood. But there is yet a further circumstance observed by Bischoff, which he thus expresses. This poisonous principle is not identical with the vivifying principle before alluded to, and which may be supposed peculiar to each individual class, and poisonous to others; for the fibrinless blood restores the animal from which it was taken, but no other animal of a different class. Hence it is argued, that blood of other classes of animals, even when deprived of fibrin, is not adapted to transfusion in the case of man.

There is a further circumstance regarding these globules which may be mentioned here—I allude to the relation between their amount in the blood, and the temperature of the animal to which it belongs. It is stated by Prevost and Dumas, to whose able researches on the subject we are much indebted, that the blood of birds is of all known animals richest in red globules; next in order stand the carnivorous and omnivorous tribes, including man; after these the herbivorous, and last of all the cold-blooded animals. Now the latest researches have arranged them in the same order with regard to their bodily temperature; and from various pathological analogies, we have little doubt of the inference which these facts suggest.

The action of these reagents upon the red particles is peculiar, and partakes of the phenomena both of the animal and vegetable kingdoms.

In human blood, the addition of water renders them indistinct, and dissolves the colouring matter; in that of the frog, they change from an elliptical to a spherical form, and un-

dergo various movements, being sometimes separated into nucleus and envelope.

The action of acetic acid is somewhat similar. Alcohol and muriatic acid have little visible effect—solutions of potash and ammonia rapidly dissolve the whole—strychnia, morphia, oxygen, and carbonic acid, effect no appreciable change in them. Müller could find no microscopic difference between the globules of venous and arterial blood.

In addition to the globules just described, blood is found to contain others, colourless, and similar to those observed in the chyle and lymph. They are insoluble in water, much less numerous than the red globules, about one-fourth their size, and in the frog are spherical. They will be further examined in a subsequent chapter.

The fluid in which the red globules are seen to be suspended, when examined with the microscope, has a slightly yellow colour, and resembles the serum, from which, however, it must be carefully distinguished. The readiest method of examining it, is to watch the coagulation of blood drawn from persons labouring under acute rheumatism or inflammatory fevers: in these cases the blood frequently coagulates very slowly, and a stratum of *liquor sanguinis* is seen to cover the surface of the yet fluid blood; in a short time this pale coloured liquid solidifies, and the *buffy coat* occupies its place.

The fluid constituent of blood, or liquor sanguinis, is without question the most important element of our frame; it is essentially concerned in most of the animal functions, excepting respiration, and appears in many forms in various parts of the body. Effused into the intestines in cholera; into the serous membranes as the substance of adhesion; upon mucous surfaces as a false membrane; extravasated in wounds as the coagulable lymph of surgeons; furnishing the materials for nutrition and secretion, it claims a large share of our attention; and as we proceed, we shall have frequent occasion to speak of it under equally important aspects.

This fluid may be procured by artificial means, as discovered lately by Müller; he found that the blood of the frog

might be easily filtered, upon the addition of a small quantity of water; and if it were required that the fluid should pass through quite colourless, this also might be secured by the substitution of a very weak syrup. He used white filtering paper previously moistened, and succeeded in performing the experiment with the blood of a single frog. In the liquid thus obtained by filtration, no globules can be detected by the microscope; in a few minutes a coagulum forms, which is not visible unless drawn out of the fluid by a needle. This gradually contracts, becomes whitish and fibrous, and has exactly the appearance of lymph.

The consideration of the liquor sanguinis leads naturally to the changes which take place in the blood after removal from its vessels, in which the liquid in question plays an essential part. These are the spontaneous coagulation of the blood, and its subsequent separation into serum and clot.

When blood is drawn from the veins of a healthy person, on being set at rest, in a few minutes it assumes the solid form. The blood of man requires from three to seven minutes, that of the rabbit only two, for coagulation. The sheep and other weak animals, yield blood which solidifies much more rapidly than that of the bullock. This difference may be well seen in the slaughter-house; in experiments which I have had occasion to perform there, sheep's blood has been found to concrete as soon as a small vessel could be filled, whereas bullocks' blood frequently remained fluid for ten minutes.

The cause of coagulation has been much discussed, and the subject unfortunately embarrassed by the statements of inaccurate observers, especially Sir Everard Home and Mr. Bauer. It was generally supposed that the colouring matter is rapidly decomposed, so that the globular nuclei are enabled to cohere; and the opinion was conceived to be supported by the fact, that on washing the clot, the hæmatosine is dissolved, leaving the colourless fibrin on the filter.

To this statement it might be sufficient to object, that the colouring matter is insoluble in serum, and the globules thus surrounded do not undergo any change for some days. In-

deed, so completely does saline matter prevent the solution of hematosine, that on dissolving it in dilute ammonia, and neutralizing with acetic acid, the salt thus formed completely precipitates it. But a still better argument may be derived from the experiment of Müller just alluded to, in which the liquor sanguinis is found to coagulate when separated by filtration from the globules; and it is well known that by stirring blood during coagulation, the fibrin of the amorphous part concretes, leaving the remainder of the blood in a fluid state. This liquid consists of serum and red globules; and what gives weight to these reasons is the fact, that the globules in both cases are entire, and have suffered no change appreciable by the microscope. These circumstances lead us to adopt a different view of the nature of coagulation, which may be thus expressed:—

The liquor sanguinis separates into two parts; *serum*, which is a saline and albuminous solution; and *fibrin*, which assumes the solid form: the latter entangles the serum and red globules, forming a jelly, which preserves the size and figure of the containing vessel.

This explanation was received in England before the time of Home and Bauer, though afterwards set aside by them. Mr. Hewson says, (1774) "It is well known that the crassamentum consists of two parts: one of which gives it solidity, and is by some called the fibrinous part of the blood; and of another, which gives the red colour to the blood, and is called the red globules." In these words he shows that the opinion was not newly broached, still less claimed by him as a discovery.

The coagulation of blood is influenced by many circumstances independent of its own condition. Among the causes which retard it, may be enumerated the exposure to a temperature considerably below 60° F., the presence of carbonic acid, exclusion of air, and the circumstance of being drawn in a full stream from the vein. It is prevented entirely by stirring blood for a few minutes, as well as by adding caustic alkalies or their neutral salts; a smaller portion of these agents serves

to retard it. Fontana states that the poison of the viper, as well as that of the ticuna, if added in small proportion to blood, produce the same effect.

The process, on the contrary, is accelerated by exposure to oxygen gas, or immersion in vacuo. The same effect is produced by dilution with water, exposure to a temperature between 90° and 110° F, the sulphates of zinc, alumina, and copper, and the circumstance of previous loss of blood in the individual.

The effect of alcohol on fresh blood is somewhat remarkable. I do not find it noticed in any work on the subject. On mixing bullock's blood with half its weight of cold strong alcohol, it remained fluid for some hours; and was at that time immediately coagulated by adding an equal bulk of additional spirit to the mixture. Numerous brown flocks were separated, leaving a colourless fluid supernatant. On repeating the experiment with human blood, the same result was obtained. The following will be probably found a true explanation: the first portion of alcohol was sufficient to destroy the contractile power of the fibrin, but the water of the blood rendered it so dilute as not to precipitate the albumen; this, however, was effected by the farther addition of alcohol.

If blood be drawn from a vein, and maintained in circumstances similar to those which belong to it in its vessels, in regard to temperature, motion, and the like, coagulation still takes place. It is true that continued motion preserves the liquid form, but it is because the clot is broken up in the serum; and the temperature is so far from retarding the process, that it appears to be of all others the most favourable to it. If blood be kept at rest within its vessel by a ligature, coagulation ensues very slowly, the time required being stated by Sir Astley Cooper at three hours and a quarter.

The coagulum thus formed does not long retain its original dimensions; it gradually contracts, and squeezes out a quantity of yellowish fluid, which is the serum. This differs from the liquor sanguinis in having deposited its fibrin in the act of coagulation. This farther change is owing to the shrinking

of the fibrin thus agglutinated carrying with it the red globules, which have as yet undergone no alteration. The proofs of this explanation rest partly on facts mentioned while considering the theory of coagulation, and partly upon such as will be adduced in treating of the buffy coat, and the *cupping* of the crassamentum. The time at which serum begins to appear on the surface of the clot will be soon alluded to, as well as the circumstances by which it is influenced.

The fluid and solid thus generated, commonly called the serum and clot, may vary much in the same specimen of blood, both in their relative amount, and in the firmness of the clot. This circumstance has been most successfully investigated by Dr. Benjamin Babington, and the result of his inquiry is contained in an essay lately published in London. He found that the ratio of the products depends much upon the figure of the vessel in which coagulation takes place:—Two portions of blood were drawn from the same person, and one allowed to coagulate in a pear-shaped vessel, the other being contained in a flat pint basin; the ratio of serum to clot was as 1000 to 1292 in the former, and as 1000 to 1717 in the latter. "In fact," observes Dr. Turner, in explanation, "when a mass of coagulating blood is contained in a spherical vessel, the particles of fibrin, being little removed from a common centre, are more powerfully attracted towards each other, yield a denser clot, and squeeze out more serum, than when the coagulation takes place in a shallow wide basin, where the particles are spread over a large surface." The size of the clot is compensated for in these cases by its texture and specific gravity.

We should take an imperfect view of the subject, did we not notice the influence of exposure to air, and a few other circumstances, both upon the time when serum begins to appear on the surface of the clot, and the amount of fluid ultimately expressed. I have to regret the small number of experiments I can bring forward upon this subject; but, such as they are, they tend to shew generally, that whatever hastens the loss of the vitality of the blood, serves also to accelerate the subse-

quent changes, as well as to diminish the ultimate contraction of the fibrin.

The first case serves to shew, that under similar circumstances the amount of contraction is not quite constant. Blood was drawn from the jugular vein of a sheep, and two bottles filled about the same time. Both were corked immediately: they were of the same shape, and placed side by side.

	Serum.	Clot.
The first yielded, .	10	11
The second, . .	10	9·5

The blood contained 4·63 in 1000 of amorphous fibrin.

Blood was drawn from the carotid of a sheep, two bottles were filled at the same moment, and a flat dish with the blood last flowing from the neck.

This flat dish, fully exposed to the air, shewed drops of serum in thirty-five minutes.

A bottle, corked till coagulation, and afterwards opened, shewed drops in fifty minutes.

A bottle corked closely, shewed serum in one hundred and ten minutes.

They furnished the following ratio of serum and clot:—

	Serum.	Clot.
Flat dish, . .	10	37
First bottle, . .	10	15
Second bottle, . .	10	13

This blood contained but 2·87 parts in 1000 of amorphous fibrin.

A young bullock was felled, and the blood received into two similar bottles. A hemispherical dish was filled with the last drawn blood. It contained 5·57 of amorphous fibrin, and solidified slowly, with the exception of that last drawn:—

	Serum.	Clot.
First bottle, . .	10	13·6
Second bottle, . .	10	18
Flat dish, . .	10	20·7

A young bullock was felled, and the jugular vein opened. The blood last drawn was obtained from the innominata. Fibrin 7·52 in 1000.

	Serum.	Clot.
A bottle drawn at first, afforded,	10	17
One filled some time after,	10	30
Last drawn blood,	10	16

From these, and similar observations, I am disposed to draw the following conclusions :—

That exposure to air, while it hastens coagulation, renders the contraction of the fibrin less perfect.

That last drawn blood, and that which contains least fibrin, coagulate soonest, and afford least serum, from want of contractile power in the fibrin.

Lastly, that whatever hastens the expression of serum, diminishes the amount ultimately separated.

In the human subject, the standard ratio of serum and clot is about 10 : 13 in health ; it is liable to much variation in disease.

In addition to these two changes which the blood undergoes, there is a third, which may be considered here, because, though a pathological phenomenon, it depends on physiological tendencies always existing in the blood. In cases of acute rheumatism, or inflammations, the blood is frequently found to be covered with a pellucid stratum, which in time contracts, and is replaced by a layer of fibrin, called the buffy coat. The source of this fibrin is now placed beyond a doubt ; the liquor sanguinis covering the yet fluid blood, coagulates by itself, and on its contracting, the fibrin assumes the appearance in question.

The subsidence of the globules is certainly the proximate cause of the buffy coat, the ulterior causes seem to be the following :—

1. Slowness of coagulation. This is proved by mixing a portion of blood with an alkaline carbonate, or receiving it under the surface of oil, as was done by Babington ; in both cases a buffy coat may be artificially obtained, while none is observed in another portion of the same blood left to itself. The influence of strong gum water is probably of a similar nature.

2. An increased amount of fibrin in the blood. This is

often stated ; but it would require an analysis to be effected by the method of stirring, and another portion of the same blood should be allowed to stand, for it is impossible to wash a clot when the buffy coat is very thick. Yet the same kind of blood that is most buffed, viz. inflammatory blood, certainly contains most fibrin.

3. An increased repulsion between the fibrin and the red globules. This opinion, though somewhat novel, may claim support from the following facts:

1. Blood of this description, when received in a thin film upon a flat surface, is found to have a peculiar mottled appearance ; this is identical with the buffy coat, and is owing to a lateral separation of fibrin and crassamentum, because they have not room to repel each other vertically.

2. When fibrin is removed from blood by stirring or shaking, the globules do not subside to any great extent in the short time allowed for comparison with the formation of the buffy coat. In the human subject they subside half an inch or more, in a few hours ; and in one case I found one and a half inches of serum on the surface, after thirty-six hours standing; but in the sheep and ox they seldom subside beyond two lines in twenty-four hours. Now, the specific gravity of serum is about 1·029, and that of fibrin 1·079, according to Babington, so that the entire liquor sanguinis is heavier than the serum, as well as possessed of more tenacity. Consequently the globules should subside much more slowly after the removal of the fibrin, were such subsidence merely owing to specific gravity.

3. By examining the clot in those cases where there is a strong buffy coat, we may be convinced that not only does the fibrin occupy a space free from colouring matter, but also that the globules are mixed with very little fibrin, so that these elements of the blood are concentrated at the opposite poles, so to speak, of the mass of crassamentum.

It will be necessary to enter upon the subject of the chemistry of the blood, in order to prove this satisfactorily, so that I must apologize for the seeming digression.

Case. Blood was taken from the arm of a boy in Dr. Alison's clinical ward, affected with cynanche laryngea; next day a thick and tough buffy coat appeared upon it. A quantity of blood weighing 3500 grains was set by itself, and its buff when washed and dried, weighed 11·7 grains. It had a delicate rose tint when moist, and a distinct fibrous appearance; the remainder of the crassamentum contained so little fibrin, that it was too grumous and friable to permit of washing. Now, had there been merely excess of fibrin, it would have been found in at least its usual proportion in the lower part of the clot. I subjoin the analysis, that it may be seen what proportion the fibrin of the buffy coat bore to the other constituents.

Clot . .	286	in 1000.
Serum . .	714	

Water	763·5
Fibrin of buffy coat . .	3·3
Seroline and oil	2·1
Globules and rest of fibrin . .	66·9
Albumen and salts . . .	164·2
	1000·0

In other cases the same result was obtained; in one instance of pneumonia 6000 grains of blood furnished 18·9 of dry buff, or 3·15 to 1000; in this instance the clot was also very friable, and in both cases much of the red precipitate appeared at the bottom of the vessel.

This red precipitate so often observed, is worthy of notice; for it depends upon red globules escaping from the clot, owing to the deficiency of fibrin, or its want of tenacity.

The formation of buff is promoted by several circumstances, being those which retard the coagulating process; among those which are likely to occur in venesection may be enumerated, a large opening in the vein, a full jet of blood, and its reception into a deep and narrow vessel.

When blood is found to be thus "buffed," it is also frequently "cupped;" that is, it presents a concave surface

above, arising from the unequal contraction of the clot ; this is owing to the increased amount of fibrin in the upper part of the mass.

The uses of these constituents of the blood, as well as their origin and changes, will be considered afterwards. The colour, electricity, and some other properties of the blood, will come under our notice in the next chapter.

CHAPTER II.

CHEMICAL CONSTITUTION OF THE BLOOD.

While considerable progress has, as we have just seen, been made in the mechanical examination of the blood, the chemical analysis has been carried somewhat further, and promises at least as rich a harvest to the followers of physiological and pathological science. It is this branch of the subject which is of so very recent an origin, having remained as a *terra incognita*, in the infancy of animal chemistry. The facts relating to it are of interest in many points of view, and not least in this, that they afford a certain means of testing the truth of former conjectures formed in accordance with the dictates of common sense, unaided by that knowledge which we now fortunately possess.

In the present day, there is increased need of caution, lest our advances in knowledge be unaccompanied by a corresponding improvement in therapeutics; and lest these interesting inquiries draw us away from those practical ends to which it is their true object to conduce; an event the more to be feared as the preliminary sciences extend from year to year. Let us not give the empiric just ground for affirming that in following the science, we have neglected the art of medicine, and are in danger of sacrificing our prospects of usefulness to the more seductive gratification of acquiring knowledge.

The ultimate analysis of animal principles has at present afforded us very little information; indeed, with the exception

of hematosine and a few others, we are little the wiser for the elaborate researches made into the nature of these substances. We therefore pass over this branch of the subject, excepting on such occasions as offer interesting facts derived from this source.

It is first proposed to give an inventory of the constituents of the blood ; next to state the alterations to which it is liable in respect of age, sex, or temperament ; after which we shall be better able to examine these elements in detail, and trace the relation of each to the mass of the blood.

Many attempts have been made to analyze this complicated fluid, and success has but sparingly rewarded the exertions of most of the competitors. But of late, the general agreement between the results arrived at by various inquirers, leads us to believe that we have tolerably well reached the truth of the matter ; and Lecanu of Paris has recently published an elaborate analysis, which we may safely take as a standard of the general constitution of the blood, though it may be necessary to correct some of the details in accordance with subsequent researches.

In two specimens of healthy blood, he found the following constituents:

Water	780·145	785·590
Fibrin	2·100	3·565
Hematosine	133·000	119·626
Albumen	65·090	69·415
Crystalline fat	2·430	4·300
Oily matter	1·310	2·270
Extractive	1·790	1·920
Albumen combined with soda	1·265	2·010
Alkaline salts	8·370	7·304
Earthy salts, iron	2·100	1·414
Loss	2·400	2·586
	1000·000	1000·000

Besides these, and some more ingredients which belong to healthy blood, there are others which enter into its composition in states of disease. It is indeed difficult to draw any

line of distinction between these two classes of its constituents, especially when we consider that all the latter do probably exist in healthy blood, though in quantity so minute as to evade our means of detection. The question is one of much interest, and in considering it in a future chapter we shall have occasion to exceed somewhat the limits of physiology, and introduce a few facts strictly belonging to the science of pathology.

A very good detail of the chemistry of the blood will be found in a recent work by Mr. Rees of Clapham; together with some further suggestions, which, if followed up, may lead to results of importance. The article in Dr. Turner's Chemistry is perhaps unequalled as a distinct and concise account of the facts at present known.

The oily matter alluded to in the above list, is contained in the serum, and may be procured from it by agitation with ether. The crystalline fatty matter is similar to cholesterine in many of its properties, and like it resists the action of potash; many of these fatty principles are described by authors, and we hear of new ones from time to time. Indeed the *fats* of the blood are almost a distinct department of chemistry, and they require a separate study. It will be at least convenient if the suggestion of Mr. Rees should prove correct, and they be found "nothing more than stearine and elaine, altered more or less in their chemical properties by combination with sulphur or phosphorus."

Dr. O'Shaughnessey has, in the "Lancet" for February 7, 1835, described a new principle found in the blood, which he has called *subrubrine;* its most striking characteristic is, that it is deposited from its solution in boiling dilute alcohol, appearing of a pale flesh colour.

The occasional presence of silica, copper, manganese, and titanic acid has been established by various observers, though in very minute quantity. The late researches of Denis seem conclusive as to the necessity of removing cholesterine from the list of ingredients of healthy blood, where it had been previously placed by some chemists.

M. Barruell has lately discovered a volatile principle in

blood, peculiar to the animal from which it is obtained, and which is not readily dissipated in drying. Probably it is in some way combined with the other elements of the blood, for it does not appear until the addition of sulphuric acid. Its odour is in all instances strongly characteristic of its species; so much so as to have been employed in medico-legal investigations. It is said to be stronger in the blood of man than of woman.

After what has been said of the serum and clot, it will be sufficient to add, that the former contains all the above ingredients, with the exception of fibrin and hematosine; the clot consists of these two principles, saturated with serum, and in a certain manner combined with it.

The physiological variations in the blood, in regard of age, sex, and temperament, form a new department of science, the study of which originated with Lecanu. In shortly stating the result of his inquiries, I shall omit decimals, as indicating a degree of accuracy not justified by the state of our knowledge. He found the amount of water to vary in health, from 779· to 853· in 1000· parts of blood, the average being 816. In the female, it varies from 790 to 853, in the male from 779 to 805. The observations of Denis agree closely with these; he found the water in male blood to range from 805 to 732, in female blood from 848 to 750: the mean of the former is 767, and that of the latter 787.

The effect of age is not so clearly ascertained, Lecanu finding no difference in this respect, while Denis affirms that the proportion of water is somewhat greater in children and old persons than in those of a middle age.

The temperaments have a marked influence on the amount of water in the blood; Lecanu found it to vary in four experiments upon women of sanguine temperament, from 790 to 796; in four upon those of phlegmatic temperament, from 790 to 827. The average for the sanguine is therefore 793, for the phlegmatic 804. In men the sanguine average was 786, the phlegmatic 800; the difference for temperament being in men 14, in women 11.

The amount of albumen is stated to vary little under these

circumstances. It is scarcely necessary to repeat the experiments relating to the amount of coagulum in the various specimens of blood; these coincide generally with those already quoted, shewing that hæmatosine is most abundant in the sanguine temperament, and more so in man than in woman

Let us proceed to the examination of these constituents in detail.

Water. The whole of this fluid in the blood exists in the form of serum, as I shall endeavour to shew when attempting to estimate the amount of hematosine. Its quantity and variations have been just stated, and its source and destination will come before us in the last chapter.

Fibrin. We have already seen that this principle exists in two states in the blood, as a solid, forming the nuclei of the red globules, and in a fluid state in the liquor sanguinis.

No means have been devised for procuring the nuclei of human blood in sufficient quantity for analysis, though Müller has succeeded in obtaining them in some number from the blood of the frog. Indeed we are by no means certain of their being fibrin—they are probably composed of smaller globules of albumen. The fibrin is best obtained from the liquor sanguinis by receiving fresh blood into a wide-necked bottle, containing several fragments of lead, corking it, and continuing to shake it slowly and firmly for about 10 minutes. This fibrin coheres into shreds, which require careful washing, when they become rose-coloured or white, and may be dried and weighed as pure fibrin. The chemical properties of this element will be found in most works on chemistry, so that it is needless to enlarge upon them here. Its amount in the blood is very small; Lecanu found it to be 4·3 in 1000, as the mean of 22 experiments. This was obtained by washing the clot. Its specific gravity while moist is stated by Babington at 1·079, being greater than that of entire blood.

I have been able to find little decisive in books regarding the nature and amount of the nuclei of the red globules; some consider their existence as problematical, while others consider them as the sole source of the fibrin of the blood. Müller observes that there is little difference between the

amount of fibrin obtained by stirring, and that procured by washing the clot; and Lecanu is much of the same opinion.

In the following detail of experiments made upon this subject, the term *amorphous* will be applied to the fibrin of the liquor sanguinis, and that of *nuclein* to the central part of the globules.

The points I have endeavoured to ascertain are the following: 1st, Is there any constant increase in the amount of fibrin obtained by washing the clot, over that separated by stirring or shaking? and, 2d, Does any constant relation exist between the two?

After some practice in washing the clot, I found that this is best effected by chopping it into small fragments, securing it in a linen cloth, and leaving the whole in water for twenty-four hours. The mass should be squeezed occasionally, to assist the process.

The carotid of a sheep was divided, and several wide-necked bottles filled at the same moment with arterial blood.

One bottle shaken with lead yielded,—

		Grains.		
	Blood,	766	or	1000
	Fibrin,	2·2	...	2·87
One washed—	Blood,	640·	...	1000
	Fibrin,	2·2	...	3·44
One washed—	Blood,	972	...	1000
	Fibrin,	3·1	...	3·20

Mean of the two last, 3·32 in 1000.

Here the fibrin (amorphous) is 2·87, and the nuclein, by subtraction, ·45, or fibrin to nuclein as 100 : 16.

A sheep was bled in the jugular vein, and two bottles filled with the blood.

One shaken—	Blood,	3000	or	1000
	Fibrin,	13·9	...	4·63
One set to coagulate—	Blood,	925	...	1000
	Fibrin,	5·2	...	5·63

Difference for nuclein 1·00.

Fibrin of liquor sanguinis to nuclein as 100 : 21·4.

A young bullock ; jugular vein opened ; first and last bottles set to coagulate, second and third shaken.

One shaken—Blood,	.	910	or	1000
Fibrin,	.	5·5	...	5·55
One shaken—Blood,	.	2000	...	1000
Fibrin,	.	11·2	...	5·60
Mean,	.		.	5·57
One set to coagulate—Blood,	.	1808	or	1000
Fibrin,	.	12·3	...	6·65
Another coagulated—Blood,	.	3087	...	1000
Fibrin,	.	20·2	...	6·53
Mean,	.	.	.	6·59
Difference for nuclein,			.	1·02

Proportion of amorphous fibrin to nuclein as 5·57 to 1·02, or 100 : 18·3.

A four-year-old bullock was felled, and bled in the jugular vein. Two bottles were filled about the same time.

One shaken—Blood,	.	910	or	1000
Fibrin,	.	7·0	...	7·68
One coagulated—Blood,	.		...	1000
Fibrin,	.		...	9·95
Difference for nuclein,			.	2·27

Fibrin to nuclein as 100 : 29.

The next object was to repeat these experiments upon the human subject. This was not so readily effected, from the difficulty of procuring blood that would coagulate with sufficient firmness to allow of washing the clot.

The first case attempted was one of coagulable urine, when the blood contained urea. The clot was rather soft, and some globules fell off into the serum.

Blood shaken,	. .	900	or	1000
Fibrin,	. . .	4·0	...	4·44
Blood coagulated,	.	1772	...	1000
Fibrin,	. . .	8·45	...	4·77
Difference for nuclein,			.	·33

Here fibrin to nuclein as 100 : 7·5.

The next two cases afford no very satisfactory result. They rather shew that the amorphous fibrin coheres pretty well during washing, though weak enough to allow the nuclein to escape.

A young woman was bled, having general fullness and pains of the back and limbs, probably hysterical.

Blood shaken, . . .	910	or	1000
Fibrin, . . .	4·7	...	5·1
Blood coagulated, . .	2030	...	1000
Fibrin, . . .	10·05	...	5·0

Another case: A young woman complaining of pain in the side, &c.

Blood shaken, . .	1740	or	1000
Fibrin, . . .	5·7	...	3·27
Blood coagulated, . .	1874	...	1000
Fibrin, . . .	5·8	...	3·1

Want of time prevented the repetition of these experiments, as well as the extension of them to other animals. Perhaps the above are sufficient to warrant these general conclusions:

1st, The washed clot of healthy blood exceeds that obtained by shaking; and the difference is owing to the retention of the whole or a part of the nuclei.

2d, The nuclei weigh most in the strong animals, in which also the amorphous fibrin is most abundant.

3d, A slight want of tenacity in the clot, especially in human blood, prevents the retention of the nuclei.

Berzelius is of opinion, that the three principal components of blood, hematosine, fibrin, and albumen, are but modifications of the same principle. The similarity of their chemical analysis, (with the exception of iron in the case of hematosine,) and the close resemblance between the action of reagents upon each, greatly favour this supposition.

In what state of combination does fibrin exist in blood? Berzelius remarks, that most fibrin loses three-fourths of its weight in drying. Dr. Davy has given two analyses of the buffy coat, (Thesis de Sanguine); but they are not exactly suited to the solution of the present question. I have put to-

gether such observations as I have had opportunity of making, and thrown the results into a tabular form.

The first part of the table expresses the amount of dry fibrin in that which is saturated with the natural serum, and in this state pressed on paper, and weighed. It is washed before drying, to obtain the pure fibrin.

	Moist.		Dry.
Buffy coat of pneumonia,	100	contained	16·2
Deposit upon the placenta,	100	...	21·5
Polypus of the heart,	100	...	19·0

The remaining specimens shew the amount of dry fibrin in that which has been well pressed after washing.

From bullock's blood,		100	contained	28·
...		100	...	26
...		100	...	24
...		100	...	28
From human blood,	(male,)	100	...	25
...	(female,)	100	...	26

In these cases fibrin appears to be combined with three times its weight of water ; this water is not however pure : it is probably serum, as may be seen by the following analysis.

Polypus of heart above mentioned yielded,—

Water,	75·3
Fibrin,	19·0
Albumen and salts,	5·7
	100·0

Fibrinous deposit upon the placenta, furnished by Dr. J. Y. Simpson.

Water,	72·1
Oil and fat,	1·4
Albumen and salts,	5·0
Fibrin,	21·5
	100·0

It would be therefore more correct to say, that fibrin is combined with four times its weight of serous fluid.

The mucous membranes occasionally secrete fibrin, as in the case of croup and laryngitis: the shreds of the rice water dejections observed in cholera are of the same nature.

Hematosine. This substance, which exists in the blood as the colouring envelope of the red globules, is obtained pure with difficulty, from the strong resemblance between its properties and those of albumen. Like this principle, it exists in a soluble, as well as an insoluble form, and its properties will be found fully discussed in chemical works.

Hematosine is the only element of blood which contains iron. This was proved by Berzelius as long ago as 1806, notwithstanding the subsequent incorrect statements of Brande and others. Neither Berzelius nor succeeding chemists could find iron by the liquid tests, till Dr Engelhart took up the subject (Prize Essay, Göttingen, 1825); he confirmed the statements of Berzelius, and like him found iron in the ashes of hematosine, but none in the other elements of the blood. In addition to this, he decolourized solutions of hematosine by passing chlorine gas through them, by which white flocks were thrown down. On adding the various liquid tests, abundant evidence was afforded of the presence of iron.

Soluble hematosine is of a deep red or black colour, and owes its brighter tint in the blood to the presence of alkaline salts. It is reddened also by alkalies and their carbonates, and blackened by acids, even the carbonic. It is insoluble in serum and saline solutions, the former circumstance being proved by Müller to be wholly unconnected with the albumen.

Hematosine, when incinerated in the open air, yields 1·25 per cent. of ash, of which one-half is peroxide of iron. When purified by Lecanu's process, which consists in adding solution of subacetate of lead to the liquor, it yields a much larger amount of iron.

Since blood contains so much iron, a question arises, in what form does it exist? Berzelius is a warm supporter of the notion that it exists in the metallic form, combined generally with the ultimate elements of hematosine. Chlorine, he argues, is the only agent we yet know of that will set free the iron from the other constituents of liquid blood; and as chlo-

rine has a strong affinity for the metal, and none for the oxide, it is reasonable to infer that the metal exists in its deoxidized state in the blood. On the other hand, the mineral acids do not detach the iron, which they might be expected to do if it were already oxidized, and which they would not do if it were metallic.

In opposition to the reasoning of the Swedish chemist, Rose has shewn that the hematosine can be in a certain degree *revived*, after the transmission of chlorine; for if the liquid thus obtained be not filtered, and excess of ammonia added, no iron is thrown down, but a deep red colour produced. He found, that when a persalt of iron is added to hematosine, the common tests will not shew its presence; also alkalies refused to precipitate iron from mixtures with many organic substances. However, such compounds are readily decomposed by the mineral acids, from which circumstance Berzelius draws an additional argument for the metallic state.

It has however been affirmed by Menghini, that dried blood, when reduced to powder, is affected by the magnet. This, if true, would be decisive against the peroxidation of the iron; but it is denied by Sir C. Scudamore. I repeated the experiment by reducing blood to dryness, and pulverizing it in a Wedgewood mortar. On applying a polished steel magnet to the powder, a very small quantity adhered to it; but on substituting for the magnet the blade of a knife of the same degree of polish, an equal quantity attached itself to the steel. But this is by no means decisive against the metallic condition of the iron in the hematosine.

The healthy amount of hematosine is fixed by Lecanu at about 108· in 1000 of blood; but, as before noticed, it varies for sex and temperament. The method employed for ascertaining the amount of this principle is as follows:—Weighed portions of serum and clot are dried, and the residue of each weighed. These numbers are reduced to those corresponding to the serum and clot of 1000 grains of blood. We now consider all the water of the clot as having existed as serum, and consequently as having left in the clot so much of salts and albumen, as would correspond to the same quantity of water in

the serum. By subtracting this amount of salts and albumen from the dried clot, we obtain the fibrin and hematosine, and by adding it to the product of the actual serum, we obtain the whole albumen and salts.

This method was employed by Lecanu, as well as Prevost and Dumas; but Müller objects to it as being founded upon a mere supposition, viz. that all the water of blood is water of serum. But if the supposition be correct, the method of analysis is so also; and I hope to be able to prove that this is the case. The following facts tend to support the view, that the fluid with which the globules are saturated is serum, and not mere water:

1*st.* We know of no instance in which pure water is found in the system; and we have just seen the fibrin to be combined with serum.

2*d.* Supposing the globules to have been at first saturated with water, and then immersed in serum, the first effect of endosmosis would be to mix the two fluids, so as to saturate the globules with serum.

3*d.* The result of a comparative experiment. The following analysis was conducted after two distinct methods, and the accordance of their results will, I think, prove the truth of the supposition in question, though there may be some room for fallacy in the albumen adhering to the globules.

Blood was drawn from a female; clot firm, natural. Specfic gravity of serum, 1·0271 at 60° F., serum gr. 200· afforded when dried, 18·2; clot, gr. 128· gave dry matter, 39·1.

A quantity of clot, gr. 327· was chopped fine, and macerated for 15 hours in water; the solution, when carefully collected, weighed 1740· grains.

Another piece of clot was chopped, and washed for several hours; it was then macerated in pure water, till a strong solution of pure hematosine was obtained, with the exception of such albumen as might belong to the globules. This solution was poured into a tube and carefully diluted, till its colour corresponded with that of the other solution of hematosine and albumen. The fluid thus obtained, weighed 246 gr.

and yielded on drying, 7·7 gr. of hematosine. Now, if 246 gr. of solution yield 7·7 gr., then 1740 of solution of the same colour, should furnish 54·4 of colouring matter ; but the last when dried, gave 75·9 of residue. Consequently, 21·5 remain for albumen and salts. The washed residue of the clot, when dried, weighed 22·5 gr., which added to 54·4, gave 76·9 for the whole fibrin and hematosine, and 98·4 for the solid matter of the clot. I will place this analysis side by side with that furnished by the first method, that their agreement may be better seen.

	First analysis by drying.		New method by washing.
Water . .	227·2	~~~~	228·6
Albumen and salt	21·2	~~~~	21·5
Hæmatosine and fibrin	78·6	~~~~	76·9
	327·0	~~~~	327·0

As the amount of albumen differs only by three-tenths of a grain, I cannot but conclude the old method to be sufficiently accurate for all practical purposes.

Having disposed of the constituents of the clot, we now return to the serum, and this fluid we shall find most conveniently examined as a whole, as most of what concerns its individual elements has been already noticed, or will be alluded to in the last chapter. Even its most interesting element, the albumen, offers little by itself beyond its chemical nature ; and as the subject of this essay is not professedly chemical, it would be out of place to enter upon details exclusively belonging to that science.

The serum of healthy blood is a transparent, yellowish fluid, the specific gravity of which is about 1·027, or 1·029. Its reaction is slightly alkaline, which is owing to the presence of soda, almost certainly combined with albumen. This is easily proved—if we boil serum till the albumen is thrown down, the remaining solution is alkaline, and gives no precipitate on further boiling. But if we neutralize with acetic acid and boil, this portion of albumen is also rendered insoluble.

The older authors always paid attention to the "serosity," by which term they meant to describe a fluid obtained by

means of boiling serum, and squeezing the mass. More recent writers repeat their observations, probably from force of habit. Had we no means of analysis, it might be interesting to observe how much water could be expressed from hard-boiled albumen, but in the present state of science, it is difficult to see why this very unsatisfactory experiment should be so often referred to.

The analysis of serum will be at once seen by referring to Lecanu's analysis of entire blood, and subtracting from it the fibrin and hematosine. The amount of water in it is not very variable, and, it should be remembered, does not by any means correspond with its specific gravity. This is possibly owing to fat, which, while it adds to the residue, diminishes the specific gravity of the fluid. In proof of this I subjoin the following analyses, made at random from different specimens of serum :—

Case.	Sp. gr. of serum.		Contents in 1000 of serum.
Woman, Peritonitis,	1·025	.....	85·5
Girl, Pneumonia,	1·026	.....	92·1
Girl, Amenorrhea,	1·026	.....	90·5
Man, Renal Dropsy,	1·027	.....	84·0
Woman, .	1·027	.....	91·0
Man, Renal Dropsy,	1·028	.....	92·4
Woman, Pneumonia,	1·029	.....	93·1
Boy, Cynanche,	1·030	.....	109·5

Berzelius has remarked, that if a small quantity of a metallic salt be mixed with serum, and rather more caustic potash be added than is necessary for its decomposition, the oxide is not precipitated, but retained in solution by the albumen. Müller suggests the probable advantage of dissolving some medicinal substances in this manner, for the purpose of readily introducing them into the system. Berzelius remarks, that it is by this means that metallic salts and oxides are absorbed from the intestinal and other surfaces, dissolved in the serum, and expelled by the excretions. The subject seems well worthy of further inquiry.

The milky appearance of serum was first examined by Professor Traill, and found to be owing to fat, which may be re-

D

moved by ether. In his experiments, the blood employed was principally from patients suffering under hepatic disease, but as he has himself informed me, he did not consider the two circumstances as connected in any particular manner.

Though fatty matter in a free state is a morbid appearance in the serum, it is always present in a form of combination with some other ingredients of the blood. Chevreul found fat in the fibrin by acting upon it with ether, and Lecanu states that this fat contains phosphorus. Gmelin acted on fibrinless blood by alcohol, and obtained cholesterine, elaine, stearine and stearic acid. Berzelius has shown that these principles exist ready formed in the blood, and are true *educts* not *products* of the operation. Boudet also reports the existence of cholesterine in healthy blood, but I am inclined to adopt the opinion of Rees and Denis, that it does not belong to it.

The extractive matter of Marcet has been considered by Berzelius as lactate of soda: for some time the existence of lactic acid was considered doubtful, Berzelius being almost alone in contending for it: but he has lately had reason to add this instance to the number of those in which his customary accuracy has triumphed, and his researches have been confirmed by those who at first differed from him.

The salts of the blood perform several functions already understood, though we do not know that these are by any means all in which they are concerned. Their influence upon the colour of the blood will be described in the chapter upon Respiration: they also serve to render the colouring matter insoluble in serum, and to furnish acid and alkali to the secreting surfaces.

We have already noticed the influence of the salts in retarding coagulation, which is an act of aggregation of the fibrin. Now a great source of danger in fever and inflammation is the effusion of coagulable lymph into inflamed tissues: and we have reason for connecting the febrifuge powers of saline remedies, with their property of retarding such solidification of the amorphous fibrin. Two interesting questions here present themselves: Is the fibrin of the blood increased in inflammation? and, are its salts diminished? The fibrin of inflammatory

blood has been found by Jennings to reach 8 parts in 1000, and 9 by Scudamore. I have found it 6·3 in bronchitis, and 3·7 in pneumonia. In fever it is much less; to which circumstance is ascribed the rarity of fibrinous effusions in concomitant inflammations. I was in doubt whether this deficiency was owing to the difficulty of securing the whole fibrin of the clot during washing, as it is very loose and grumous in fever. Accordingly a fever patient was bled when in a state of delirium, and the blood shaken with fragments of lead: the following results were obtained:

Fibrin	1·9
Hemat. and albumen .	189·0
Water	809·1
	1000·0

The globules subsided very slowly, leaving half an inch of serum in 48 hours.

In most cases of buffy coat, the clot is too loose to admit of washing. Jennings has found the salts of the serum diminished as far as one half in cases of inflammation; they are also diminished in cholera, a circumstance possibly connected with the suppression of urine observed in that disease.

One of the most remarkable properties of the serum, is the effect which it has in promoting or retarding coagulation. Much has been said on the subject of its retarding this change; but Hewson, Van der Kolk, and Professor Alison stand alone in ascribing to it the opposite property. The subject has been lately taken up by Mr. Prater, in his Physiological Enquiry, &c. His experiments reconcile the apparently contradictory statements, and confirm the truth of both. He begins by tracing the influence of pure water upon fresh blood, and finds that it hastens coagulation, but most so when mixed in equal proportion with the blood. He found that ox-blood, which became solid in 8 minutes, underwent that change in 3, when mixed with an equal bulk of water: thus much therefore is due to this element.

On substituting serum of the same species for pure water,

he found the effect still greater: the blood of a sheep coagulated *instantly* when mixed with one-fifth part of its bulk of serum, though a portion of the same specimen left unmixed for comparison, did not become solid for one minute and a half. The blood of a bullock, which coagulated in 8 minutes, became solid in two minutes, whether mixed with one-half, one-third, one-sixth, or even one-tenth part of its bulk of serum from an ox previously killed: on the other hand, the process was not perceptibly hastened by the addition of one-fifth part of water.

Thus it is evident, that the addition of serum in small amount possesses a power of hastening coagulation, not depending upon its watery nature: and this power must reside in the albumen or in the salts contained in it. It is not likely that it belongs to the albumen, as this is rather diminished during bleeding, notwithstanding the increased tendency of the blood to solidify. Mr. Prater traced it to the saline ingredients of serum by direct experiment: he found that small quantities of carbonate of soda and chloride of sodium do actually hasten coagulation, but they must be added in very minute proportion; 1-64th part of saturated solution of carbonate of soda retained the fluidity of the blood for one hour. The degree of dilution has a great influence: for two parts of serum served to hasten decidedly the coagulation of one of blood, notwithstanding the large amount of saline matter.

The opposite power of serum in retarding coagulation, has been known since the time of Hewson, by whom it was employed in keeping blood liquid for microscopical experiments. The benefit derived from salt in cholera and yellow fever has been partly explained on the same principle. The sero-sanguineous fluids found in post mortem examinations probably owe their fluidity to the same cause: though they often seem to consist of serum mixed with red globules washed from the clots contained in the parts.

The rapid coagulation of blood last flowing from a dying animal has long been observed. This has been generally attributed to a mere loss of vitality, analogous to that experi-

enced by the solids ; but we can now furnish a much more interesting and satisfactory explanation.

The first point ascertained is, that during long hemorrhage the blood is gradually found to become more watery, and less abundant in red globules. This was first proved experimentally by Prevost and Dumas, who bled a cat three times, with an interval of two minutes between the first and second, and five minutes between the second and third operation. The blood drawn each time contained the following :

	Water.	Albumen.	Globules.
First bleeding . .	791	87	118
Second bleeding .	809	74	116
Third bleeding . .	829	77	93

A similar result was obtained by Lecanu in the human subject. The result of my own observations on this subject will be related presently.

In the next place, the experiments of Majendie and others have proved that venesection produces increased absorption ; in addition to this the capillaries are enabled to contract upon their contents, the whole amount of the blood being lessened, so that much of the serum contained in them is circulated through the system. To these two facts we are to ascribe what I shall soon have an opportunity of proving, viz. that the serum, after hemorrhage, is both increased in quantity, and diminished in specific gravity. Moreover, the absorption consequent upon venesection is greatest in the capillaries ; and by these means, as observed by Professor Alison, the blood is so far charged with serum as to coagulate much more rapidly. Thus the chain of causation seems complete ; and we may add this to the number of instances in which we are permitted by our Creator to enter into the means by which He has secured results so conducive to our safety. For we cannot but observe the benefits which result from this property of the blood, in the case of wounds and hemorrhages ; the greater the difficulty of stopping the flow of blood artificially, the more do the circumstances of the case tend to a spontaneous favourable termination ; and on the other hand, did the loss of blood diminish its power of coagulation, it is difficult

to see how any considerable hemorrhage could ever terminate successfully, without the application of violent remedies.

Many substances which possess the power of preventing coagulation, lose this property when sufficiently diluted. A remarkable instance is mentioned by Mr. Prater: "half a dram of opium dissolved in half an ounce of water, and added to half an ounce of sheep's blood, kept it permanently fluid; yet it *coagulated* when mixed with two parts of water sixty hours afterwards." Strong saline solutions produced similar effects, as well as many other chemical agents. The same observer mentions a remarkable difference between the citric and tartaric acids in this respect; the latter, if added to blood in minute proportion, changed the colour, and prevented its subsequent coagulation, even on the addition of water. Citric acid, on the contrary, produces no change in the colour of blood when mixed with it in small quantity, and on dilution with water coagulation takes place. "Is the peculiar action of citric acid in any way connected with its specific effect over scurvy?" (P. 26, op. cit.)

In this place I may mention the experiments which have been performed with the view of ascertaining the change passing upon blood in the course of long hemorrhage. This does not include the variations experienced by the blood in consequence of repeated venesections at intervals of one or more days, which will be stated at a future opportunity, but those which arise in it, at the time of the diminution of its amount, owing to an effort of nature to supply the deficiency.

The observations of Prevost and Dumas just related, shew that the water of blood is increased in these circumstances, and its globules diminished in quantity. Davy found the specific gravity of entire blood diminished, as the following instances will shew:

	First drawn.	Last drawn.
Sheep	1050	1044
Lamb	1051	1045
Ox	1058	1051

The few observations I have made upon this subject are directed to answering these questions:—

1*st*, Is the density of the blood diminished by the loss of its globules, or of its albumen ?

2*d*, Is the fibrin increased or diminished ?

A four-year-old bullock was felled, and bled in the jugular vein ; when almost drained of blood, the vena innominata was opened, and the last-drawn blood thus procured.

		First blood.	Last blood.
Relative amount of	Serum	28	37
	Clot	72	63
Sp. gr. of serum		1·0264	1·0257
Sp. gr. of clot		1·067	1·054

A young bullock similarly treated.

Relative amount of	Serum	25	38
	Clot	75	62
Sp. gr. of serum		1·0236	1·0223
Sp. gr. of clot		1·078	1·070

These facts, as far as their number will allow, warrant the following conclusions. The clot of last drawn blood is both lighter and less in size, indicating a considerable diminution in globules ; the serum is more abundant, and at the same time more watery.

2*d*, Is the fibrin diminished or increased in the course of hemorrhage ? The following experiments furnish an answer to this question :

Fibrin in 1000 parts of blood.

	First drawn.	Last	Difference.
Arterial blood, sheep	3·32	3·9	·58
Venous, young bullock	6·59	7·08	·49
Venous, four-year-old bullock	9·95	10·5	·55

Few as these instances are, their close accordance gives them some weight, and they lead to the conclusion that fibrin increases in blood towards the close of long hemorrhage, to the extent of ·5 in 1000 grains. Such a result is rather extraordinary, for we should not have expected that the fibrin of the liquor sanguinis would increase, while its albumen is found to diminish. Does it in any way bear upon the amount of fibrin in inflammation, and the possibility of diminishing it by venesection ? The time elapsing between

the flow of the first and last drawn blood, was about five minutes.

Before leaving the chemistry of the blood, a few circumstances remain to be noticed,—as its electricity, colour, and internal movements. On the last point, much has been said at different times, but the statements of the observers have neither agreed with each other, nor has the same physiologist always succeeded in confirming the results which at first he conceived himself to have arrived at.

Of the motions observed by Schultz during circulation, by Heidmann during coagulation, by Tourdes and Circaud under the action of galvanism, and by Treviranus in blood just drawn, none have been confirmed by subsequent inquirers, and most of them have been traced to other causes, as drying up of fluids, shriveling of tissues under the solar ray, and the like.

A self-propellent power has been ascribed to the blood by Treviranus, Carus, Doellinger, and Oesterreicher, in accordance with the original notion of Kielmeyer. This subject will be found fully discussed by Müller in his "Physiology," by whom it is, I think, satisfactorily disproved. More recently, similar statements have been made in our own country, but it is probable that they will share the fate of the former.

The analysis of the blood by galvanism has been described at length by Dutrochet, and extraordinary results affirmed to have been obtained. Müller undertook an elaborate inquiry into the subject, and traced the supposed production of muscular fibre of Dutrochet to the coagulation of albumen by galvanic action. He has refuted most of the observations of Dutrochet upon the subject, and shewn that they may be easily explained upon principles already well-known. In all such experiments, the greatest caution is necessary in making allowance for collateral circumstances, as the effect of galvanism upon pure water, salts, and albumen. Nor is the agent employed of such a nature as to warrant hastily-conducted experiments, or conclusions rashly deduced from them. For it is an element with whose nature we are scarcely acquainted, and by means of which many brilliant results have been already obtained,—whose velocity in traversing material objects,

"time counts not," and whose "close and mysterious struggle" with the atoms of matter, is only revealed by consequences more or less remote.

The colour of the blood, and the changes effected in it by gaseous and saline agencies, will come before us under the head of Respiration, yet a few considerations respecting it belong to this place. It must have occurred to the most superficial observer, that while we speak of the blood as red, we universally describe the veins as blue. This circumstance is alluded to by Hunter, who also remarks the fact, that a thin layer of fibrin gives the same blue colour to blood in a basin. I have also seen blood unequally covered with a buffy coat, having an indigo tint in some parts, while others exhibited the red or the buffy appearance. This may help to account for the blue tint of the subcutaneous veins ; but there is another modifying circumstance,—the opposition of flesh colour around the vein, causes it to assume in many instances a distinct green appearance, on the principle of complementary colours well known to artists. Besides this, the blue may be changed to green, from being seen through a yellowish medium.

The colour of the blood answers several useful purposes. We may first consider its importance in disease: By it we are enabled to judge of the amount of congestion or inflammation in external parts, and even in many cases, of the malignity of the disease. (Hunter, on Blood and Inflammation.) It forms an adjunct to the diagnosis of inflammation,—*rubor*, *calor*, *tensio*, *dolor* ;* we may by its means detect extravasation in putrid diseases,—and in case of bruises, the successive changes of colour are owing to the gradual absorption of the constituents of effused blood.

Though infiltration of blood after death gives us much trouble in the form of pseudo-morbid appearances, its presence in inflamed tissues furnishes much useful information, and even during life, the glow upon the face and hands affords a ready indication of the state of health.

* In hematemesis, hemoptysis, and hematuria, as well as in the sputa of pneumonia, its presence is most important in the diagnosis and indications.

The moral uses of the colour of blood are twofold. By its distribution over the whole cutaneous system, it is impossible to wound the body by penetrating instruments, without extravasating some of this fluid; hence the word *bloodshed* has become a general expression for the destruction of life. Owing to the intense colour of blood, and the difficulty of removing its stain after coagulation has taken place, it becomes a most formidable "witness" against the murderer. This idea will be found fully expanded in the tragedy of Macbeth, *passim*, and very beautifully employed in the following lines, where the Corsair is described as noticing the crimson stain on the face of Gulnare:—

> "That spot of blood, that light but guilty streak,
> Had banished all the beauty from her cheek."

Again, the involuntary expression of our emotions by blushing and paleness, serve as a check upon our natural tendency to deceive our neighbour, at times when we cannot impose upon ourselves. We may indeed learn to counteract this expression of our feelings by the vascular system, and by force of habit may

> "Quench the blushes of ingenuous shame;"

but we are not so constituted by nature, nor has the acquisition of this power by any means tended to increase the confidence which should exist between man and man.

From the blood variously disposed under the skin are derived almost all those tints which add so much to personal beauty. The older poets of England were especially in the habit of referring to these sanguine tints as elements of beauty; and the profusion of imagery employed by them in illustration of the subject, sufficiently attests their talent and diligence.

Though it is difficult to know how far to ascribe our predilections to force of habit, we cannot but think that blue, yellow, or green, would form but a poor substitute for the "purple light of love," and the tints of jaundice, chlorosis, or cyanosis, would require a long time to allow us to become reconciled to them. Were this the proper place for such inquiries, it would be interesting to trace the red colour

through some of its principal localities in the kingdoms of nature, and to see it generally connected with strength, warmth, and animation. It occupies the first position in the prism, as being the least refrangible ray; it is the colour generally assumed by flame, and incandescent bodies; and is perhaps the only one to which any animals are known to have a decided aversion.

CHAPTER III.

EFFECTS OF RESPIRATION ON THE BLOOD.

We have hitherto considered the blood as possessed of constant properties, and endeavoured to describe it by the characters common to it in the veins, arteries, and extreme capillaries. But it is obvious, that this method of investigation, though convenient as far as it goes, is by no means perfect; for in these situations the blood undergoes changes in colour and composition, which materially affect its organic relations. Among these are, arterialization, which takes place in the pulmonary capillaries, and its counterpart, deoxidation, which is effected in those of the systemic circulation. To these we shall for the present confine our attention, recollecting that whatever is accomplished in the one, nearly the reverse must take place in the other. It is equally evident, that the function of respiration is necessarily dependent upon a circulation previously established; and it has been already shewn, that the blood respires less for its own sake than on account of structures remote from the lungs.

The capability of respiration is recognized in medico-legal questions, as the first sign of independent life; and its termination is pretty well marked by the cessation of this act. Though in man a slight suspension generally proves fatal, many of the lower animals are remarkable for the comparative facility with which they can dispense with it. Birds are dis-

tinguished by the fullest enjoyment of this function; they inhale a large volume of air,—and the capacity of their lungs, the amount of red globules in their blood, their high animal temperature, and the contrivances for the circulation of air through their bodies, place them at the head of all organized creatures in the scale of respiration.

We cannot as yet affirm with certainty, whether this function should be considered as intended to discharge a mere excretion from the blood, of something which would prove injurious if retained,—as the carbonic acid, which appears to produce coma if allowed to reach the brain in any quantity,—or whether we should view it as a means of adding something to the blood, which shall remove its noxious tendencies, and enable it to perform certain functions. Some physiologists have gone the length of asserting that the chief object is to remove carbonic acid, which they affirm acts as a poison on the brain. To this opinion are opposed the experiments of Edwards, who found frogs to live longer when circulating dark blood, than when deprived of the greater part of that fluid by hemorrhage. Dr. Alison has remarked, that until this question is settled, we do not know whether to view the high degree of atmospheric agency upon the blood observed in some animals, as the cause or the effect of the intensity of vital functions which accompanies it.

In speaking of this subject, Dr. Alison advances an interesting view of the nature of asphyxia, as connected with the present subject. From some facts which he has collected from various sources, he draws the conclusion, that in death from this cause, the nervous system first suffers from the effects of venous blood; next, and most fatally, the capillaries of the lungs, and in a less degree only the heart and other muscles. As the physiology of the blood is not generally understood to include the laws of circulation, it would be out of place to enlarge upon this and similar subjects.

It is stated on the authority of Berzelius, and we have many opportunities of verifying the assertion in particular cases, that all moist organic substances convert into carbonic acid a portion of the oxygen in contact with them, so that

the red particles of the blood differ from other structures in possessing this property in a higher degree. All the following observations upon the changes produced in the blood by air, refer exclusively to the red globules.

The most convenient method of disposing of a subject so extensive as the present, appears to be, to state first such points as may be considered proved, together with the evidence on which they rest, and then to examine the theories which claim support from them. The following facts are allowed on all hands :—

1. Of the air received into the lungs, part of the oxygen is retained, and a nearly equal volume of carbonic acid returned in its place, together with a variable amount of aqueous vapour.

2. The portion of blood transmitted through the pulmonary arteries and veins, has lost the dark modena hue, and acquired a red tint called arterial: together with which it receives a power of supporting life, which it did not possess before.

3. A portion of nitrogen is absorbed, and another portion evolved, generally nearly equal, but not always so.

4. On removing a portion of venous blood from the body, and agitating it with atmospheric air, oxygen is absorbed, carbonic acid evolved, and the red colour of arterial blood produced.

This fact is sufficiently attested by the change of colour; but the experiments made with the view of ascertaining the amount of gases evolved and absorbed, have not furnished any striking evidence in its favour. They may be related here, as serving to make us careful on other occasions, and leading us not to expect too decisive a result in similar inquiries, which will come before us presently.

Several early experimenters, especially Sir H. Davy, ascertained that blood would absorb oxygen, and give out carbonic acid in less volume. But as their observations are not so accurate as may be desired, we will turn to the later researches of Professors Christison and Müller. The former removed the fibrin from blood by agitation with lead in a stopped bottle, exposed the blood to the influence of air, with which the

bottle was partially filled, and transferred the gaseous contents to the mercurial trough, by stop-cocks and a funnel. In all his experiments, thirteen in number, there was a diminution of the volume of air; and the quantity of carbonic acid evolved was always less than that of the oxygen absorbed. Ten cubic inches of blood were found to condense from 0·57 to 1·4 cubic inches of oxygen, and to yield ·25 of carbonic acid.

These experiments were repeated by Müller, who continued the agitation of the blood with air for a longer time, but does not seem to have improved upon the process. He procured half a cubic inch of carbonic acid from ten cubic inches of air, agitated with seven of pig's blood.

In all the experiments made upon this subject, sufficient attention does not seem to have been paid to the hygrometric state of the gases. The air passed into the bottles of blood was most probably not saturated with moisture, a condition which it would quickly acquire in that situation, and an increase of volume would follow. But this air, transferred from a liquid at the maximum of moisture, to a mercurial jar in contact with pure potash, must suffer a material diminution, which would in this case be solely attributed to the absorption of carbonic acid. Supposing no change to pass upon the gases by the action of the blood, yet in every instance there must be upon the whole, diminution of the air eventually, and a considerable decrease on the introduction of caustic potash. I suggest this source of fallacy with deference; but cannot help attributing some of the result to this cause, at least in the experiments of Müller, who distinctly states that he introduced caustic potash at once into the receiver. In Dr. Christison's process, liquid alkalies were employed, so that this source of error was avoided.

5. The crassamentum of arterial blood is blackened when its serum is removed by washing, and no exposure to oxygen will then redden it. This is well proved by an experiment performed by the late Dr. Edward Turner in conjunction with Dr. Quain of London. (Turner's Elements of Chemistry.—Blood.)

6. According to Nysten, the introduction of oxygen into

the veins will redden the blood, without the evolution of carbonic acid, or any change in the quantity of saline matter.

7. All acids, even the carbonic, have the property of rendering the blood dark-coloured.

8. Saline solutions, and serum, have the property of reddening venous blood even in vacuo; and no oxygen is absorbed, or carbonic acid evolved, on reddening blood in close vessels by such fluids. This statement is so important as to require pretty full proof, which the reader may easily repeat for himself.

Some experiments of Dr. Stevens are the only ones which would lead us to infer, that venous blood, which has not been exposed to the air, can be thus reddened by exposure to saline agency. The observations of Turner and others, upon arterial blood darkened by removal of serum, are not applicable on the present occasion. The following experiments were therefore performed:—

Venous blood was received into a wide-mouthed bottle, and carefully corked. When the serum had well separated, the liquid was poured off, and the bottle quickly immersed in water recently boiled to exclude oxygen. A tube previously filled with boiled solution of bicarbonate of soda, was inverted under water over the mouth of the bottle, so that its contents soon exchanged places with the water surrounding the clot. A dull red colour assumed the place of the dark tint of the clot.

To avoid any fallacy, the mode of experimenting was somewhat changed. Another bottle filled in the same manner, was uncorked under water, so as not to disturb the serum surrounding the clot. A small tube filled with a strong solution of carbonate of potash, was allowed to stand till the bubbles of air had risen to the surface, and then inverted over the blood, so that its contents flowed into the serum surrounding the clot. A bright red colour was produced, equal to that of arterial blood.

There is a degree of difficulty in the matter of reddening blood by serum, which I have not seen alluded to. When a venous clot is cut into, the surface is found almost perfectly black, far more so than those parts which, without having ac-

cess to the air, are partly reddened by the contact of free serum. It is possible that the penetration of gases allows of a degree of aëration through the covering of serum ; this might be determined by corking bottles accurately, and observing whether or not this difference is then observed. Otherwise it is difficult to conceive that the simple expression of an uncombined fluid, by a force so slight as that which holds together the clot, could alter the colour of hematosine. These portions are still saturated with serum, as I have proved by analysing the clot ; and if any farther addition of that fluid surrounding it, can change its colour and composition, are we not in fact allowing that some chemical agents have the power of acting at sensible distances?

9. No carbonic acid can be obtained from venous blood by heat ; nor does arterial blood evolve oxygen in similar circumstances.

Though Sir H. Davy, and some others, have at times stated the contrary, the truth of this assertion is abundantly proved by the more accurate experiments of Müller and Bergemann, Strohmeyer and Dr. J. Davy ; Professor Magnus has also shewn the reason why carbonic acid cannot be procured from the blood in this manner ; the temperature required to set free carbonic acid, is sufficient to coagulate the albumen, in which case its extrication is effectually prevented.

We now enter upon the consideration of three very important questions, which have but lately been in any degree decided. They will require a more lengthened examination, as much depends upon the answers which we can furnish to them.

Q. 1. Does venous blood contain carbonic acid, and arterial blood oxygen?

There are four methods of procuring such gases from blood, supposing them to exist ready formed in it ; by heat, which has been already shewn to be unsuccessful ; by the air-pump ; by agitation with hydrogen or nitrogen ; and by passing either of these gases through the blood.

The air-pump has at length succeeded in extracting carbonic acid from blood, in the hands of Magnus and Bischoff. I

quote these as authorities, because they are the only ones on which we can depend; the experiments of Brande, Home, Bauer, and others, are too inaccurate to merit our consideration in opposition to those of Müller, Mitscherlich, Strohmeyer, Tiedemann, Gmelin, &c. Magnus has shown that no carbonic acid is evolved until the air in the receiver supports only one inch of mercury. The quantity of gas procured by this method is small, whereas Brande asserted that venous blood yielded twice its bulk of carbonic acid.

Mitscherlich and Gmelin found the whole of the aeriform matter evolved by blood under the air-pump to be re-absorbed on restoring the pressure; from this they inferred that it was vapour of water; this reasoning does not appear very satisfactory, for whatever was disengaged from the blood, might with equal facility be re-absorbed by it.

The next method of procuring gases from blood is to agitate it with hydrogen or nitrogen. This was first attempted by Stevens and Hoffmann, and while we must give them credit for the idea, the experiments of Hoffman, and the earlier ones of Dr. Stevens, are too inaccurate to have any weight in so difficult an inquiry. Besides, the value of an experiment is much lessened, when described in terms relating to a preconceived theory.

Mr. Hoffman of Margate received blood into a bottle of pure hydrogen gas, so as to exclude atmospheric air; after shaking for some time, "the gas was no longer inflammable." Such a result is opposed to all we know upon the subject, greatly exceeding that obtained by atmospheric air; it is therefore probable that the gas had escaped. The circumstance that lime water was rendered turbid, is not very material, as a very small amount of carbonic acid will effeet this, and some air might have entered along with the current of blood. Besides, all such experiments should be expressed in numbers, and repeated, so that any fallacy may be detected.

Dr. Stevens' experiments go to prove these points:—That the bubbles obtained from venous blood, under the air-pump, contain no carbonic acid.

That hydrogen gas standing over fresh blood, and exposed

to the action of the air-pump, furnishes no carbonic acid : but this gas is procured by agitation, under similar circumstances.

Atmospheric air gave the same result ; that is, no carbonic acid was obtained when the air was drawn off immediately, but only after being allowed to stand for some time.

Serum agitated with carbonic acid so as to absorb a portion of it, evolved none by exposure to hydrogen gas.

Now, we know that atmospheric air instantly arterializes the blood in contact with it, and carbonic acid should therefore have been found in both the above instances in which blood was exposed to it. As baryta is an exceedingly delicate test, and the first moments of exposure must be the most effectual, this fact greatly lessens the value of the experiments.

The following experiments were made before I was aware of the late researches of Magnus, and while the question of carbonic acid in the blood was still undecided. Though somewhat long, I prefer relating them in detail, as the reader may judge of their accuracy by those precautions or oversights on which so much of the value of such attempts must depend.

The subject of experiment was venous blood from the jugular of a bullock which had just been felled. The enlarged extremity of a bent tube was applied to the vein, and the other end plunged below the surface of good animal oil, which filled wide-necked bottles to the depth of one inch ; as soon as the oil flowed freely from the mouth of a bottle, it was corked, so that no air got access to the blood at any period. The bottles, which were previously charged with fragments of lead, were shaken for some time, and conveyed to the apartment where the experiment was to be continued. Pure hydrogen gas was now procured by passing it through a mixture of lime and potash in solution, contained in a tube closed at each end ; the whole was agitated till impurities were removed, and the gas perfectly saturated with moisture.

The tube containing gas was immersed in a bottle of water at 55° F., the barometer standing at 29·47 inches ; it was now measured by the application of a graduated scale, on which each entire inch was divided into thirty-two parts.

Each bottle of prepared blood was carefully uncorked be-

neath the surface of water, the floating fibrin picked out with the forceps, and the tube of hydrogen fitted into its neck. On inverting the whole, the gas passed into the bottle of blood, and a leathered cork was substituted for the tube. The bottles thus charged were immersed in a water bath at 57° F. and repeatedly shaken during 24 hours.

The tube used for measuring was next filled with prepared venous blood (that is, fibrinless) and inverted over a funnel, which was also so placed under water, as to receive all the gas passed into it out of each bottle. As it was fully charged with vapour, it was reduced to the same temperature of 55° F., and immediately measured. The prepared blood was exchanged for lime water, the tube shaken till absorption ceased, and being once more immersed in the bath, the residual gas was finally measured. The barometer was constant, and the thermometric and hygrometric condition of the gas unchanged. The following results were obtained :

Two ounces of blood, exposed to $\frac{46}{32}$ of a cubic inch of hydrogen for twenty-four hours, reduced the volume of the gas to 45·5, and after the removal of carbonic acid, it was 43·5. Consequently 2·5 parts of hydrogen were absorbed, and 2· of carbonic acid evolved.

Four ounces of blood were shaken with 46 parts of hydrogen for the same time, the gas measured 45·5 next day, and after the action of lime water 44. In this experiment, 2· parts of hydrogen were absorbed, and 1·5 of carbonic acid evolved. The lime water was rendered milky in both instances.

Had I the necessary time and opportunities, I would have repeated these experiments in a modified form ; though the uniformity of the results here obtained, as well as in other instances in which I was not quite certain of accuracy, gave me little hope of obtaining a different conclusion. I cannot pass by some objections which may be made to the steps of this experiment.

The oil could not well have hindered the action of air or gas upon the blood, on account of the free transmission of gases through thin layers of such fluids and solids. The lead employed did not appear to have become carbonated, for it was

equally bright before and after the experiment. The small amount of gas employed was intended to facilitate the measurement of minute variations in its bulk. The utmost care was employed in the preparation of the hydrogen; the vessels were filled with dilute acid to exclude air, and muriatic acid poured upon nails to extricate the gas. The gas was allowed to remain in contact with the blood as long as could be safely attempted without fear of commencing putrefaction, in which circumstance I was guided by some experiments of Berzelius. The removal of fibrin was no hindrance to arterialization, for the same blood reddened by exposure to air even after forty-eight hours.

It should be stated, that in no instance were the vesicular bubbles of blood reddened by the gas, a circumstance which will presently be made use of.

These experiments would lead to the conclusion that a small quantity of carbonic acid is contained in venous blood, and may be extracted from it by agitation with hydrogen gas; and that hydrogen does not possess the property of arterializing blood, as lately asserted by Dr. Stevens.

But the most decisive evidence of the presence of carbonic acid in blood, is obtained by passing hydrogen or nitrogen gas through the blood. The superior efficacy of this method lies in this, that the gases disengaged are not liable to be reabsorbed by remaining in contact with the blood, to which circumstance may probably be attributed the very small amount preserved on the last occasion. Bertuch and Magnus, (Archiv. für. Anat. und Physiologie, 1836) as also Gmelin and Bischoff, have fully established the fact, that hydrogen as well as nitrogen will extract carbonic acid from the blood to the same amount to which oxygen or atmospheric air will do. In the case of hydrogen, Magnus obtained at least one-sixth of the volume of the blood. As the experiments are elaborate, it will be sufficient to repeat the conclusions to which they lead.

Both venous and arterial blood contain carbonic acid, nitrogen, and oxygen; the venous contains most carbonic acid, and arterial most oxygen; the nitrogen does not always differ.

The quantity of gas contained in blood, amounts to one-

tenth on an average, and sometimes one-eighth of the volume of the blood; the oxygen of venous blood equals $\frac{1}{4}$—$\frac{1}{5}$ of the carbonic acid, while that of arterial blood equals $\frac{1}{3}$—$\frac{1}{2}$ of the last mentioned gas. From one-fourth to one-tenth of the whole gas is nitrogen.

Q. 2. Will any gases besides atmospheric air extract carbonic acid from blood?

This question has been already answered in the affirmative; both hydrogen and nitrogen possess this power, and that to an equal extent with atmospheric air.

Q. 3. Is carbonic acid exhaled from the lungs of cold-blooded animals in an atmosphere of pure hydrogen or pure nitrogen?

These questions are borrowed from Müller's late work on physiology, from which many of the preceding facts are quoted. The answer to this question was first supplied by Spallanzani, who shewed that cold-blooded animals exhaled nearly as much carbonic acid in gases containing no oxygen, as in atmospheric air. M. Edwards obtained a similar result; but as these earlier experiments were liable to many sources of error, which we are now able to avoid, it will be as well to mention the results of those lately performed by Müller and Bergemann. From the method of purifying the gases, the precaution of introducing chloride of calcium before caustic potash, the exhaustion of the frogs before filling them with hydrogen, and the like, there seems no room for fallacy in their results. It is well worth observing, that either of these gases, hydrogen and nitrogen, could allow of the exhalation of carbonic acid, and that in equal quantity. The following conclusions were drawn by Müller:

A frog confined in pure hydrogen or nitrogen for six or twelve hours, exhales from ·3 to ·96 cubic inch English of carbonic acid: whereas the average amount of carbonic acid exhaled in atmospheric air by a frog, during six hours, is ·68 cubic inch English.

Bischoff has also found, that from a frog, whose lungs had

been tied and cut out, carbonic acid was exhaled by the skin, to the amount of ·24 inch in eight hours.

Having settled these much disputed points, let us briefly review what we have learnt, so as to prepare ourselves for some explanation of the process of respiration. We have seen that blood contains three gases, oxygen, nitrogen, and carbonic acid; that it is prepared to absorb oxygen whenever it comes in contact with it, and that it will evolve carbonic acid whenever exposed to a gas free from that acid: that is, in atmospheres of oxygen, nitrogen, hydrogen, or atmospheric air, but not in vacuo; that such evolution of carbonic acid is independent of solid structures, and even of vitality, for it takes place with equal facility in the lungs, skin, open air, and in blood four days removed from the body; and, lastly, that such gaseous changes influence the colour of the blood, in a manner quite distinct from that of saline impregnation, and altogether independent of it. In proof of the last statement, I refer to the experiments quoted at pp. 46—49. I have also observed the circumstance, that blood from the vein of an ox, as well as that from the human subject, after being kept four days, reddened on being agitated with air for a few minutes.

There is an additional fact which has not yet been alluded to, but which I hope to prove; that blood, being supplied at all times with oxygen and carbonic acid, is continually employed, even when removed from the capillaries, in converting the former gas into the latter. Hunter relates several cases to prove that the blood soon becomes dark by stagnation in an artery; that it is darker in the arm than in the hand or foot; and that during fainting, it flows from the vein of a scarlet colour. Now these go some way towards shewing, that the dark colour of blood is gradually acquired, and not all at once in the extreme capillaries. I have found that venous blood from which the fibrin was removed, and which was arterialized by shaking, became dark on standing for a few hours, that it might be reddened by agitation, and become dark again. This may be accounted for by supposing that the blood continues to convert a portion of the oxygen contained in it into carbonic acid, and as this takes place while the blood

is contained in the large vessels, or after removal from the body, it appears that blood has a power of thus acting upon gaseous matters, common to fixed oils, plants, and according to Berzelius, all organized bodies.

From these facts I am inclined to deduce the following theory of respiration, which nearly agrees with that of Lagrange and Hassenfratz :—

Venous blood is exposed to atmospheric agency, through the medium of a thin pulmonary membrane ; by this means an opportunity is afforded to it, first, of absorbing an additional amount of oxygen, and secondly, of expelling part of its carbonic acid, by its tendency to exchange places with a dissimilar gas.

If this theory prove correct, the function of counter-respiration, *venization*, or deoxidation of blood will be something of this nature ; the oxygen brought from the lungs is acted upon partly by the blood in which it is dissolved, but principally by capillary structures, so as to be converted into carbonic acid, which would accumulate to an injurious amount, were it not got rid of by respiration.

During this investigation, the following facts may have been noticed. 1st, Carbonic acid is not so hurtful to life as commonly supposed, since it exists to a considerable amount in arterial blood. 2d, The reddening of blood is rather due to absorption of oxygen than evolution of carbonic acid, for Nysten produced this effect by injecting oxygen into the veins, without any gas being disengaged. Moreover, blood is not reddened when its carbonic acid is removed by hydrogen or nitrogen, as will presently be shewn. 3d, The reddening of blood by salts and alkalies, is in the present state of our knowledge, quite unconnected with the same change of colour as produced by oxygen, and in the case of deficient respiration, would prove but a fictitious imitation. 4th, The presence of a certain amount of saline matter is necessary to the production of the red tint by oxygen.

Several theories have been offered to account for the phenomena of respiration, but from various facts already mentioned, we are now entitled to reject most of them. That of

Dr. Stevens is highly ingenious, and one, which if true, would furnish information very important in a pathological point of view ; it is as follows.

Carbonic acid, says Dr. Stevens, blackens venous blood, by preventing the salts from exerting their rubefacient influence upon it. The admission of oxygen "draws out the carbonic acid by a latent power of attraction," and the red tint is consequently restored. Dr. Stevens does not stop here ; he goes on to ascribe to oxygen a power which he denies to nitrogen, which gas, he says, has no such "attraction" for carbonic acid; "this we know," says he, "is not the case, for an animal almost instantly dies when we force it to breathe an atmosphere of nitrogen or any *other* gas which does not possess the power of drawing out the acid from the blood." But he allows that hydrogen does possess this power, and endeavours to support the supposition by those experiments made to prove the presence of carbonic acid in the blood. By this means he accounts for cold-blooded animals breathing an atmosphere of hydrogen, as in Spallanzani's experiments. He excludes oxygen from all share in producing the change of colour, otherwise than by "drawing out" the carbonic acid. To this theory there are several objections, and from what we have already seen, it will be suffieient to enumerate them. Oxygen *does* redden blood without evolution of carbonic acid ; cold-blooded animals breathe equally well in pure nitrogen and pure hydrogen. Nitrogen and hydrogen have an equal power of extracting carbonic acid from blood, and where they do so, they do not render it by any means lighter-coloured. With the view of ascertaining this point, I half filled a spherical bottle with blood, and giving it a smart shock, so as to raise large vesicular bubbles, watched the change of colour. In atmospheric air they underwent the change from Modena colour to bright scarlet in about ten seconds, though the mass of blood remained unaltered. When hydrogen was employed, the bubbles underwent no change of colour, though the experiment was repeated several times. Dr. Stevens probably foresaw this objection, for he says that hydrogen renders blood dark-coloured. This does not, however, appear to be the case

according to the observations of Professor Müller. The reader will find many ingenious arguments in Dr. Stevens' work on the blood, together with many facts and suggestions, on account of which humanity is already deeply indebted to this most original inquirer. Second to none in ardour, it is to be wished that some of his conclusions were drawn with greater caution, and founded upon more accurate experiments.

The acid theory of Mitsherlich, Gmelin, and Tiedemann, as well as the secretion theory of Edwards, are at length disproved by the researches of Magnus, and the discovery of gases in the blood.

That of Lagrange and Hassenfratz, as already stated, is nearly identical with the view adopted in the present essay. The notion of De Maack deserves attention, who considers the hematosine as analogous to hydrated protocarbonate of iron, which gives off its carbonic acid on combining with an additional dose of oxygen.

We have now traced the blood from the right side of the heart to the left, and endeavoured to explain the causes and nature of the important change effected during its transit; and have stated that it undergoes a corresponding, though directly opposite alteration in its progress from the left to the right side of that organ. Of this change we have little to say here in addition to what has been previously hinted regarding it; and it will come before our notice very fully in a future chapter. But the blood undergoes other alterations of which, at present, we know but little, and it is almost impossible to say whether such a circumstance, as excess of fibrin in arterial blood, may arise from addition in the pulmonary, or subtraction in the systemic capillaries. The change of density may equally arise from exhalation in the one case, and absorption or secretion in the other; we can only state that such and such differences are found to exist, without knowing whether or not they are in any degree connected with respiration.

The fibrin of arterial blood is to that of venous blood as 29 to 24, according to the analysis of Denis and Müller. The temperature of arterial blood is from 1° to 1·5° F. above that

of venous blood, and its specific gravity as 1·047 to 1·050, according to Dr. J. Davy. The relative capacity for heat is still doubtful. The ultimate analysis of different kinds of blood has not yet furnished any satisfactory results.

The general influence of respiration upon the blood, is to communicate to it a power of stimulating the organized solids; it is indispensable to life, and we know of no method of supplying its deficiency. Its importance is best studied by observing cases of morbus cæruleus, bronchitis, and other diseases where this function is imperfectly performed.

CHAPTER IV.

ON THE VITALITY OF THE BLOOD.

We now enter upon the discussion of a question of some importance, and on which much difference of opinion still exists—Does the blood possess vitality?

To this question three answers have been given:—1*st*, By those who believe in the vital principle as a distinct constituent of our frame, it is generally said that this element is resident in the blood as well as in the solid structures. 2*dly*, Some of those who consider life as the sum of the actions of organized bodies, ascribe the property of vitality exclusively to the solids; and, 3*dly*, Some consider it as common to the blood and solids.

With this last view of the subject I agree; and shall proceed at once to discuss briefiy the arguments which have been, or may be, adduced upon both sides of the question, considering the *onus probandi* to lie more in bringing forward positive arguments, than in attempting systematically to refute the objections adduced by others.

Before attempting to prove that blood is endowed with vitality, it is necessary to define strictly what is here intended by the expression. And upon the answer to these two questions will depend the propriety of the title of the present essay; for if the blood be merely a mechanical stimulus to the solids, it would be as incorrect to speak of its physiology, as of the physiology of the water that turns a mill, or the river

that overflows a country and leaves a fertilizing deposit to enrich the land. But if the blood possess actual life, we must leave entirely this hydraulic view of the subject, and go the length of Treviranus, who speaks of the biography *(biologie)* of organic structures. The term physiology can only be applicable in the case of the blood being endowed with that description of vitality which is resident in muscles, and other organized solids.

The existence of life as a distinct entity was scarcely called in question, till the researches of modern science clashed with the unanimous opinion of mankind from the earliest times. The point is by no means decided at present, as some of the first physiologists of the day still adhere to the good old notion ; and though much in the minority in the scientific world, they are well supported by the popular opinion of most nations. If we refer to those systems of religion which have been received by the most philosophic nations of antiquity, we find abundant evidence of their universal agreement upon this point. Prometheus first formed his statue of clay, and then added fire from heaven as a distinct constituent. Hermes Trismegistus handed down the notion of elementary fire which he received from the ancient Brahmins ; and Thales and Pythagoras taught the same doctrine which they had learnt from the Pastophori of Egypt. Various schools improved upon the philosophy of their predecessors, and not content with giving " a name " to this mysterious element, assigned to it also a " local habitation." It was the reputed denizen of the heart, the liver, and the brain ; it presided over functions sufficient to engage it in the most unremitting employment ; it was at the same moment engaged in nourishing the body, and yet dependent for its own existence upon the due performance of that function.

The Alcoran furnishes proofs of the generality of this belief, and Virgil thus describes the death of a hero :

" Purpuream vomit ille animam ;"

thus identifying the principle of life with the circulating fluid.

But it is needless to multiply quotations from these sources. There is but one statement of sufficient importance to merit our consideration, and that being contained in Holy Writ, should be examined with reverence and careful attention. In the account of the creation given in Genesis, these words occur —"The Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life, and he became a living soul." If we must understand these words literally as containing an exact account of the process of creation, we should be driven to the conclusion that man consists of at least two principles,—the terrestrial body, the breath of life, (or vital principle,) and a soul, which is not here alluded to. Besides, as the soul is not distinctly mentioned, we should be led to suppose that it is included either in that part which was formed of the dust of the ground, or that which was infused during the first act of respiration: in other words, we would either embrace materialism, or deny the immortality of the soul. But the Bible was not written to teach men science. It is called the "foolishness of preaching," a term quite inapplicable, if it contain superhuman lessons of physical science. To set aside all arguments drawn from the Bible in favour of a distinct vital principle, it is sufficient to prove that this idea was at the time an element of popular physiology; for we find that men are always addressed by their Creator in such language as they best understand, and may least distract their attention by contradicting their notions regarding the material world.

The same observations will apply to an analogous statement contained in the Book of Leviticus, that "the life of the flesh is in the blood." We still employ similar expressions in daily conversation, when we speak of "life blood," or apostrophize the "blood in our veins." Pope's phrase—

"Vital spark of heavenly flame,"

precisely embodies the idea acted on by Prometheus. Indeed, the opinion of the mass of mankind upon this subject has undergone little alteration from the time of that fabulous age till the present, when Franklin, like a second Prometheus, drew

fire from heaven, by a more literal, though scarce less dangerous method.

To the existence of a distinct vital principle it may be objected, 1st, That we know nothing of its properties, and have no means of proving its existence.

2d, That all the phenomena of organized bodies may be equally well explained by the supposition of vitality or irritability resident in such bodies, which, being acted on by certain stimuli gives rise to the manifestation of vital action.

3d, On the system of a vital principle, life must precede organization, since it superintends the process of organo-genesy; but to say also, that life is dependent upon organization, is incompatible with the former assertion. Yet this latter is strictly true, and the difficulty may be avoided by stating, that *life is the sum of the actions of a being possessed of vitality*; or, in other words, life is a result, produced by the action of certain stimuli upon matter possessed of vitality or irritability.

We now return to the original question, Does the blood share the property of vitality with the solids? The arguments generally adduced in the affirmative may be thus stated:—

I. The fluidity of blood while circulating in its vessels, when contrasted with its coagulation on removal from them. We cannot explain this on the principle of motion, galvanism, temperature, or renewal of substance; and however difficult it may be to state logically the argument deduced from these facts, their force must be evident to the unbiassed mind. Why is the blood a fluid? Its composition is similar to that of the solids, in amount of water, chemical composition, and mechanical arrangement into globular and amorphous substance. Bordeu observed, "*Le sang est de la chair coulante*;" and I cannot sympathize with those who speak of it as revolting to their common sense to ascribe vitality to a fluid. When we look at the offices performed by the blood, its intimate connection with the solids in the capillaries, (which, by the bye, are the seat of nutrition, secretion, and the origin of most diseases,) and its use in respiration as just described, it is strange that the property of fluidity, by which its sphere of action is so much extended, should be brought forward as an argument

against its vitality. If the amount of water entering into its composition be an objection, what shall we say to the brain, which contains a larger proportion; or to the *sea medusa*, of which several pounds of gelatinous substance contain but a few grains of solid matter?

With regard to its fluidity, we have a parallel case in the seminal secretion, to which vitality can scarcely be denied; for the semen impregnates eggs after their removal from the body, as in the case of fishes and batrachia; and tendencies to disease are transmitted by the father, as well as conformation and family resemblance. The whole subject of coagulation has been already fully discussed.

II. The blood furnishes the material for the solids: it intervenes between the processes of digestion and nutrition. In what part, then, of this chain of action does vitality commence? The food is not possessed of it, for it is decomposed before being absorbed; the chyle does not coagulate at first, but it does so when contained in the thoracic duct. Hence it appears to have acquired vitality during its passage through living parts: if so, the blood is composed of materials previously vitalized. The blood is formed before the solids, and preceded only by the germinal membrane; so that of the present constituents of our frame, the blood is the first formed, and the source of all the rest.

It is therefore the medium by which vitality is communicated from the parent to the offspring: besides, the albumen of the ovum is fluid; and in the case of oviparous animals, the germinal membrane possesses very little more consistency or organization.

III. The circumstances modifying coagulation furnish the following arguments:—

1st, Those conditions of the system which are marked by a low state of vitality, present blood possessed of a very feeble power of coagulation; and when we find a high degree of bodily temperature, with strong vascular excitement, the blood coagulates firmly, and the crassamentum contracts remarkably. On the other hand, if the coagulation were a mere chemical change passing upon the blood, we should observe it equally

solid in all kinds of death. This is not the case; for in sudden death, from many causes, it remains fluid, and its fluidity is generally accompanied by a flaccidity of the muscles. This, however, is not constant. Dr. Percy has lately communicated to me a case where a person died of violent gastro-enteric inflammation; the muscles were quite rigid after death, but the blood remained fluid.

2dly, The tendency of blood to coagulate, and the degree of accuracy with which this change is effected, are influenced by various agents, much in the same manner in which actions undoubtedly vital are modified by them. Coagulation is entirely prevented by freezing for 36 hours, by a heat of 140° F. which is insufficient to coagulute the albumen: and much retarded by opium, as first observed by Dr. Hunter, and since confirmed by Mr. Prater, (Experimental Inquiry, p. 42). But the most forcible application of this argument is, I think, that derived from the analogy between the action of some medicinal agents upon the fibrin of blood, and upon that which is the basis of muscle. Thus we know that chloride of sodium has far greater power than opium in preventing the contraction of pieces of muscle immersed in its solution; and according to Mr. Murray (Brewster's Journal) hydrocyanic acid has still less effect than opium in this particular. Now these three substances, chloride of sodium, opium, and hydrocyanic acid, have a proportional influence upon the coagulation of the blood: the first being able to prevent it altogether, at least until subsequent dilution, the second to retard it considerably, and the third being so feeble in its effect, as to have been affirmed by Sir C. Scudamore to be without any influence at all. Mr. Prater, however, finds that in large quantities it certainly does retard coagulaion.

It would be uncandid not to mention a few circumstances that oppose this view of the subject, though perhaps they might be easily reconciled with it upon further investigation. Prater discovered (op. cit. p. 6.) that blood kept fluid by common salt might be carefully evaporated to dryness, and yet retain its power of coagulation when mixed with a sufficient

quantity of water. He accounts for this by quoting Spallanzani's experiments in drying muscular fibre, after which he moistened it with water, and found that it renewed its contractile power. He then goes on to offer a suggestion, that the fibrin of blood possesses contractility similar to that of muscle, though less in degree, for which reason it is longer retained.

Freezing is not necessarily destructive of vitality: from this Fletcher (Physiology, p. 49.) draws an argument against the vitality of the blood, for, says he, if it has none after freezing, it is probable that it did not possess it before. The same accomplished writer has also remarked, that the solids are now proved not to be globular, but fibrous, so that the structure of the blood is little in favour of its vitality. It would be easy to answer these objections, and Fletcher does not attach any great importance to them.

In order to render this view of the subject applicable to existing facts, it is necessary to look upon coagulation as the last vital act performed by the blood: this notion was started by Dr. Hunter, who conceived it to be effected by means of what he called "the stimulus of death." I do not see any good reason for adopting such an expression, but am inclined to agree with Dr. Alison in ascribing to blood two properties, attraction and repulsion; and though this supposition may seem unphilosophical, it is resorted to as the only known method of accounting for the phenomena observed.

IV. The facts stated in a former chapter regarding the contraction of the clot, and the repulsion of the globules by fibrin in the case of buffy coat, furnish several arguments in favour of the vitality of the blood. Their general force lies in this, that they prove the blood to be influenced by physical agents in such a manner as cannot be explained by reference to the laws of inanimate substances; whereas they admit of an easy explanation on the supposition that this fluid is endowed with vitality.

It is not asserted that the vitality of the blood is of the same intensity as that of the muscular fibre: it is generally allowed that tendinous structures possess an inferior degree to

that enjoyed by the last mentioned tissue, and there seems no reason why we should deny to different structures a gradation in their powers of vitality.

The objection to this line of reasoning, as well as some additional arguments which do not appear to me very satisfactory, will be found in most systematic works upon Physiology. Upon the side of the vitality of blood will be found Sir Charles Bell, Professor Alison, Prater, Thackrah, J. Hunter, Mayo, Grainger, Burrows, Albinus, Müller of Berlin, &c.; and to these stand opposed Thomson, Elliotson, Fletcher, Magendie, Milligan, and others.

The question is not one of mere speculation, but must bear very materially upon our therapeutics: for we cannot reasonably hope to produce alteration in a vitalized fluid, by treating it as though entirely inert, and incapable of receiving or transmitting vital impressions.

CHAPTER V.

ON THE ORGANIC RELATIONS OF THE BLOOD.

In treating of the physiology of the blood, it is not customary to enter upon the laws of its circulation, nor even to consider its distribution and relative amount in the different parts of the system. But to render the subject complete, we should study this fluid as possessed of a beginning and an end, as well as endowed with certain properties at any one period of its existence. The remark has been made by Dr. Alison, that all organized bodies possess three characteristics in common,—an origin, growth, and termination. This holds true of the blood as an element of such bodies, even in a further sense than what is here intended. For not only does the blood undergo the same changes as its containing solids, but there is a constant necessity for the production of fresh blood, to supply the waste incurred in the functions of nutrition and secretion. And there is the more inducement to attempt a sketch of this department of the subject, as it seems no author has yet brought together the facts known regarding it, so as to lay them before us in relative order,—facts which, however interesting in themselves, might become more attractive by such historical arrangement. To these facts already known, I hope to add in some degree by such researches as I have had the opportunity of prosecuting.

The subject naturally divides itself into two distinct parts, the one tracing the blood from its origin in the embryo to its termination at death: and the other following it from its imperfect state in the chylopoietic viscera, to its ultimate

destination in the animal economy. The former of these departments must be very briefly discussed. The blood is seen in the embryo at a very early period, in the circumference of the area vasculosa of the germinal membrane. In all animals its globules are spherical at first, and do not appear elliptical in birds till the eighth day. These globules seem to be composed of several smaller ones, probably the albuminous globules of the egg: they are gradually incorporated, and resolved into a pellicle and nucleus.

At this early period no such organs as liver, spleen, or lungs, exist in the embryo; the blood being entirely formed between, and from the substance of, the two layers of the germinal membrane. But this membrane is not found after birth, so that we must ascribe the process of sanguification, to no particular organs of the body, but to the influence of those general vital conditions which exist both in fœtal and extra-uterine life.

Of all the elements of our frame, few enjoy a greater extension of function than the blood at the moment of birth. Charged with abundance of oxygen, by the rapid breathing of infancy, and freely propelled through the soft and delicate tissues by the agency of an active circulation, it soon assumes that condition which remains with little appreciable alteration till the time of old age. Some remarks have been already quoted from Lecanu, and beyond these we can only infer the probable changes which the blood undergoes in composition during the periods of dentition, ossification, and puberty. We have reason to suppose that some difference must be produced by the separation of the materials for semen, for milk, and for the fluids of the menstrual evacuation. Did we understand these subjects, we might find room for therapeutic improvement in many particulars; and perhaps most of our present means of cure might be found actually adapted to such emergencies. To give one instance from many: Since menstruation produces a considerable loss of hematosine, we we might suppose deficiency of hematosine to be a predisposing cause of amenorrhœa: Now, as iron is a necessary ingredient of colouring matter, and its exhibition in this disease is

of decided benefit, we are led to ask, whether this is a mere coincidence, or whether we may rationally take such a view of the pathology and therapeutics of amenorrhœa, as the facts would lead us to adopt. Mr. Jennings has found deficiency of hematosine in such cases, and I have had one opportunity of verifying his observation.

The age of the patient was 18, the retentio mensium of six month's standing, and the chlorotic appearance well marked; the first bleeding offered the following results:

Water . . .	781·0*
Fibrin . . .	5·7
Hematosine . .	81·8
Albumen and Salts .	131·5
	1000·0

During the last moments of life, the blood is often found to coagulate in the heart, or, to speak more correctly, the fibrin coagulates, including a variable amount of the red particles in its substance. In this change the chordæ tendineæ and valves of the heart perform the part of the lead used in shaking blood, or the rod in stirring. They entangle the fibrin as it begins to cohere from deficient vitality, and it is frequently found adhering to them. Under the article *fibrin* such a polypus has been described, and the result of its analysis related.

We are often struck with the small amount of blood found in the vessels after death; this may be partly accounted for when we recollect that after coagulation the clot contracts to half its bulk, and the serum so effused would be absorbed by the surrounding parts. This circumstance should be taken into account when we attempt to detect sugar, urea, or cholesterine in the parenchymatous organs.

In passing on to the second division of the subject, we begin by considering whence the blood is derived, and what are the steps of the conversion of food into this highly elabor-

* This case offers a remarkable instance of deviation from the general amount of constituents—the only deficiency is that of iron—the sum of albumen and hematosine being regular.

ated fluid? In this interesting inquiry we must not expect complete success; we must often be contented to follow nature, our guide, "with wandering steps and slow," and must not be disappointed should we at times miss our road, and have to rejoin her at distant intervals. When we look at the blood as exposed to the continual depredations of every structure through which it passes, and find every part of the body enriched at its expense, we naturally inquire whence such expenditure is supplied, and to what organs so important a function is entrusted. The answer to these questions is what we now attempt to furnish.

Blood is composed of matter derived from three sources; lymph, as conveyed by its proper vessels; chyle by the lacteals; and the materials introduced by venous absorption. Of this last, we know little, owing to the nature of the case, which prevents our observing such substances in their rapid passage from the solids into the capillary veins. The experiments of Magendie and others furnish almost all our information on this point.

Lymph is the vehicle of many poisonous matters, such as the virus of syphilis and cancer, as shewn by the affection of the glands consequent upon such diseases. It is a transparent fluid of a pale yellow tint, is slightly alkaline, and has a saline taste; that modification of it termed chyle, differs from it in a few properties, which will be noticed presently.

These fluids possess many properties in common, among which are the faculty of spontaneous coagulation, and the existence of globules suspended in them. The chyle possesses all the ingredients of lymph, with the addition of fat, which makes it opaque, and yellower than pure lymph. It contains more soluble fibrin, as well as more globules. Human lymph has been microscopically examined by Müller, who observed its coagulation, which he describes as arising from the agglutination of fibrin previously dissolved, and not of the globules. Both chyle and lymph separate into serum and clot.

The lymph of the horse has been found to contain 57· of albumen, and 3·3 of fibrin in 1000 parts. Both these fluids contain all the principal ingredients of blood excepting the he-

matosine. The proper chyle globules are quite distinct from those of fat, which may be removed by ether. The fat depends greatly on the nature of the food, and often rises to the surface of the chyle like cream. But the true globules are of constant size, measuring, according to Prevost and Dumas, $\frac{1}{7200}$ of an inch in diameter, that is, almost half the size of the blood globules. They have been already alluded to as existing in the blood.

It was found by Emmert, that chyle differs in its composition in each of the three following localities ; the intestinal lacteals, the receptaculum chyli, and the middle and upper part of the thoracic duct. That taken from the lacteals is milk-white, does not change when exposed to the air, and does not coagulate. The contents of the receptaculum are slightly reddened by atmospheric influence, and yield a small clot. The more highly elaborated chyle from the middle of the duct, reddens almost like the blood when exposed to air, and affords a firm and bulky crassamentum. The admixture of watery lymph renders the chyle in the upper part of the duct less rich than that in the middle.

Tiedemann and Gmelin confirmed the observations of Emmert, and pursued the inquiry further. They traced the red colour of chyle to the presence of hematosine, derived from the lymphatics of the abdominal viscera. This accounts for the fact, that such colour is most strongly marked when the food is least nourishing, owing to the preponderance of the lymph over the chyle in that instance. The colouring principle was identified with hematosine, by the green tint communicated to it on the addition of hydrosulphuric acid.

It is often said, that respiration is a last step in the process of digestion, since it converts the chyle into blood. We may with much reason doubt this, for the chyle globules may be detected in the general circulation after having passed through the pulmonary. Now the blood is so thoroughly exposed to the air, that if any exposure would redden these globules, we should not recognize them in their colourless form in venous blood. Besides, there are none of them in an intermediate state between chyle globules and those proper to the blood,

which we should expect to see, were they reddened gradually by distinct additions of oxygen.

The following seems a ready method of shewing the chyle globules in the aggregate, in the blood. When two portions of blood are drawn from the same person, one of which is allowed to coagulate, and the other deprived of fibrin by shaking with lead, we have an opportunity of comparing the serum expressed from the clot, with that procured by the subsidence of the red globules. My attention was not drawn to this circumstance till lately, but in the last three experiments of the kind, I found the serum of shaken blood milky, while that from the cogulation of the same specimen was transparent. This seems owing to chyle globules, which escape the fibrin when coagulated by stirring, but are entangled in the clot when coagulation takes place in the usual manner. These three patients were bled at noon.

It is proposed to pass on generally to the uses of blood, and having traced this fluid to its destination in the functions of nutrition, apposition, and secretion, to return to the individual constituents, endeavouring to put together such facts as can be collected regarding each of them, so as to present a connected view of their natural history. The changes which the blood undergoes during its existence as a whole, are those of arterialization and venization, which have been already considered. We therefore pass on to the next question—What becomes of the blood?

Blood is disposed of by transformation, which is of three kinds: 1st, Apposition, or growth of non-vascular textures: 2d, Nutrition, or growth of vascular textures: and, 3d, Secretion, or transformation into a fluid which escapes on the free surface of the organ.

Apposition, or the mode by which non-vascular textures are nourished, is effected by the change of some of the components of the blood into a solid unorganized substance, on the free surface of an organ. We have little to do with this function at present, for whatever part the blood plays in it, will be best explained by the study of nutrition generally. It should be remembered that non-vascular structures are of two kinds; 1st, those that were originally vascular, and have had

their vessels obliterated by the accumulation of earthy matter, as the shells of crustacea, the antlers (but not horns) of the deer, and some other structures; and, 2d, those which are produced by means of a vascular matrix, as the horns, teeth, crystalline lens, and nails. The young antlers of the reindeer are said to be eaten by the Lapland hunter when hard pressed for food.

Nutrition is a true *intussucception* or transformation of the components of the blood into the organized substance of the different textures.

The nourishment and growth of the body is perhaps the most astonishing example of the power of life in producing results which not only accord at different periods, but in so many individual beings. Great as must be our admiration on witnessing the regularity of reproduction of our muscular or cerebral tissue,—what must we think of the first formation of them in the embyro, where there is no ground-work to be filled up, and their developement from the germinal membrane seems little short of the result of a direct creative power? The laws by which these effects are determined, are not so fixed and invariable, but that we are frequently able to modify them by therapeutic agency; and unfortunately for humanity, they are too often influenced by innumerable morbific causes.

Before attempting a definition of this function, it is necessary to discuss one or two theories which are of interest regarding it: the first of these is, that which considers nutrition to be effected by the appropriation of the blood globules to the solid textures. To this we may oppose the following objections:—

1st, The blood globules are flattened discs, whereas the muscular and nervous fibrils are merely swelled into spherical inequalities. This is proved by the researches of Ehrenberg, Müller, and Schultz.

2d, The blood globules are not simple, but composed of a nucleus and envelope.

3d, The muscular and nervous fibrils are from five to eight times smaller than they would be if so formed; indeed no capillaries could enter to supply them with globules.

Now as the red globules cannot reach these minute structures, unless by passing between them in the larger capillaries, we conclude that nutrition is effected by means of the liquor sanguinis. There are some further reasons for this belief.

In a full grown man, using moderate exercise and aliment, the functions of nutrition and absorption are for a time exactly balanced. If then we know what matter is absorbed, we have a pretty correct notion of what is deposited. We have already seen the lymph taken up by its proper vessels, as the effete material of the tissues; and have noticed that this fluid agrees in almost every respect with the liquor sanguinis. Thus we have additional grounds for concluding that nutrition is confined to the liquor sanguinis, seeing it is the exact counterpart to the products of absorption.

I cannot resist offering a comparative view of the circulating system as existing in red-blooded animals, and those invertebrata whose blood is white or colourless.

In these last the circulating fluid appears to be merely liquor sanguinis, and the offices of nutrition and secretion go on by means of it. The same holds good in mammalia, where the liquor sanguinis is circulated through arteries from the heart, and restored to it by veins and lymphatics. But these have another system of circulation—one by which red globules are sent from the lungs to the extreme capillaries, and by means of which additional functions are performed, as those of diffusion of oxygen, and probably animal heat. For as Prevost and Dumas have shewn, the amount of red globules is greatest in birds, whose temperature is also highest, and least in frogs and fish, whose heat is little elevated above that of the surrounding medium.

Thus we have two systems of circulation, the one colourless, connected with nutrition and secretion, and the other red, belonging to respiration and animal heat. For the sake of convenience these two are incorporated into one—the fluid is made to suspend the solid, and assist in its transit through the structures. But the two circulations do not coincide in extent. Hunter remarked that the globules do not reach so far in the capillaries as the liquor sanguinis; and he states

that in the chick the latter fluid is formed before the globules. Since the globules are so well employed in one way, we are quite prepared to find them excluded from another function.

Another theory which has lately been adopted or revived is this, that all the constituents of our frame exist ready formed in the blood.

This point cannot be settled one way or the other as a whole, for both sides of the question claim support from facts certainly ascertained.

Some elements of the blood, as albumen and fat, appear identical with those existing in the solid organs; but many constituents of the latter are not found in the circulating mass. The fibrin of muscle can scarcely be considered as identical with that of blood; and our only excuse for applying the same name to both, is the present imperfect state of animal chemistry.

Gelatin, or the substance converted into it by boiling, cannot be detected in the blood, though salts, phosphorus, and lactic acid, are contained ready formed in it.

There are three modes by which the elements of blood may be applied to the growth of vascular textures,—nutrition, hypertrophy, and inflammation. The two first are almost the same in nature, though differing in degree. The third is essentially different. The uterus affords a ready instance of these varieties, in its growth during early life, its hypertrophy in the pregnant state, and its inflammation so frequent after delivery. In the last case fibrin is deposited as well as in the others; but this as well as albumen is in inflammation accumulated between the particles of the tissues, and not assimilated to them. Besides, the deposit of inflammation is the same in every organ, without reference to the original tissue.

We thus define nutrition: The component parts of a tissue attract to themselves certain principles contained in the liqnor sanguinis, changing the composition of those that are dissimilar, and adding to themselves those that are homogeneous: further, the newly assimilated particles partake of the vital properties of those to which they have been recently attached.

On this subject Müller makes an interesting remark with

regard to cachectic diseases: in scrophula, syphilis, and some others, the liquor sanguinis appears to suffer, for the nutrition suffers much, and the glands of the lymphatics are deeply affected. But in scurvy, the glands do not suffer, and the globules of the blood appear most changed by the morbid influence. This seems to pave the way for some broad pathological distinction, between diseases of the globules and those of the liquor sanguinis.

Secretion is of two kinds as regards the blood; all other distinctions need not be attended to at present. First, The separation from the blood of the substances previously existing in it, as urea, (this may be termed *excretion)*; and, secondly, the formation of new principles by the secreting organs.

Secretion differs from nutrition principally in this, that the substance secreted escapes from the particles which first attracted it. Several questions of much importance relate to the subject of secretion, which we shall now consider at some length.

I. Do the materials of a secretion exist ready formed in the blood?

This question must be answered in detail, for we cannot give a general negative or affirmative reply. It is best discussed by stating what means we possess of determining the point for individual principles: for we must recollect that every secretion has its characteristic proximate element, as urea in urine, *speichelstoff* in saliva, &c. Their absence, suppression, or metastasis, is a mark of disease.

1st, We may detect the secreted principle in the blood, while the organ is in full performance of its secreting function. The albumen of serous fluids, the salts and lactic acid of the urine and perspiration may be always found in the blood.

2d, We may find the principle in the blood after the complete removal of the organ destined to secrete it. As long as the organ remains, the fact of bile, &c. in blood is worth nothing, since it may be refluent from the hepatic capillaries.

3d, When a substance appears simultaneously at several secreting organs, we may safely infer its presence in the blood at the time. Thus sugar of diabetes is found in the urine,

and, according to MacGregor, in the saliva; and bile in the cornea, urine and skin of jaundice.

4th, As far as I am acquainted, no organ can secrete a new principle in disease, unless previously contained in the blood; hence its abnormal appearance in a secretion is decisive of its constitutional origin.

By applying these laws, we shall find presently that casseum, cholesterine, and biliary matter, are formed extemporaneously by their secreting organs; and albumen, urea, and sugar, belong originally to the blood.

II. Are these materials exclusively supplied by the liquor sanguinis?

From what has been already said, it is evident that this is the case in all instances, excepting the menstrual discharge. This, if it be a true secretion, differs from all others in this particular. The case of pus will be considered presently.

III. Is the secretion of an organ complementary to the portion of the atom of liquor sanguinis used for its nutrition?

This ingenious idea merits brief discussion, at the risk of being somewhat foreign to the present subject. It does not apply at all to the true secretions, but only to those *excreted* from the blood. It will be sufficient to mention briefly the consequences that would follow, unless some further provision were made for removing the matter deposited; were this supposition true,

1st, Urea would be found in every part of the body except the kidney, and the kidney would consist almost entirely of albumen.

2d, The kidney, as furnishing the largest secretion, would soon become the largest gland in the body, and the liver, instead of being the driest, would be the most watery of the glandular structures.

3d, All non-glandular parts would be identical in composition, since the whole of the fluid elements of blood would be equally appropriated by them; no one considers the brain and muscles in any way similar in compositon.

4th, In some diseases the size of the gland would undergo immense alteration. In diabetes, the kidney would fill the

whole abdomen, unless the absorbent system were equally enlarged.

It would be easy to object to these arguments, though it is scarcely necessary to pursue the subject further. The reverse supposition, that a gland and its secretion contain the same principles, is still more untenable.

Secretions appear to differ in different organs in accordance with the same general vital laws that determine the variety of nutrition.

IV. Do any secretions partake of the vitality of the blood? This question may be very shortly answered. The milk does not; for though containing some globules, it is decomposed in the stomach of the infant, which would imply a waste of vitality, were it endowed with such a property. The case of semen has been already discussed, and concerning the rest, few have had any doubts.

V. Are diseased secretions subject to fixed laws? In this inquiry no attention will be paid to the antagonism of secretions, and such subjects; the only object being to ascertain the laws which regulate the connexion between these secretions and the blood. The following are offered as an attempt towards elucidating the subject.

1st, No organ possesses the power of secreting an abnormal principle, unless such principle exist ready formed in the blood.

The albuminous urine of renal dropsy, and the fibrinous deposit of croup and pericarditis, are no exceptions to this remark; the peritoneum will secrete caseum in suppression of milk, and the kidney sugar or bile in diabetes or jaundice, but all these exist previously in the blood. An apparent exception may be found in pus. This may be found at any time and in any part of the body; yet it possesses globules not found in the blood. Setting aside the question of a pyogenic membrane, it has been lately shown by Hodgkin, Lister, and Raspail, that pus globules are principally fat, and that they are not contained in pus at the first moment of its formation.

Examples are recorded of vicarious secretions of milk, but Autenrieth has shown that such do not contain butter and

sugar of milk, but only the albumen that would have furnished these principles. This seems to be the extent to which nature can go in remedying these defects, to secrete the materials that should have been removed by the absent or ineffective gland. We hear of menstrual evacuation by metastasis, but we have no proof of any thing beyond blood being so effused.

2d, An alteration in an excretory secretion must be accompanied by a change in the blood, either as a cause or an effect.

If, for example, the blood be originally healthy, and the kidney affected with granular degeneration, the composition of the blood soon varies. This is effected by the abstraction of albumen, and non-elimination of urea. It is scarcely necessary to add instances, as the next law will afford some. The only case which seems to me as an exception, is where the secretion from the organ exactly balances the alteration in the blood, as in the amount of water in diabetes, where I found the specific gravity of the blood 1·0532, and its analysis as follows :—

Water	814·8
Albumen and salts . . .	94·2
Hemat. and fibrin . .	91·0
	1000·0

About twenty pounds of urine were passed daily.

In a case of Bright's kidney, the urine contained 13·4 of albumen in 1000, specific gravity 1·026, and quantity three pounds daily. The blood was little changed.

Specific gravity of serum .	1·028	
Water in blood . . .		776·8
Albumen and salts . . .		80·6
Hematosine and fibrin . .		132·6

Other instances may be found in cholera, where the blood is found deficient in watery parts, which have been effused into the intestines. The specific gravity of the serum in this disease has been found as high as 1·040.

The opposite case is illustrated by diabetes, where the sugar

is found in the urine, in consequence of its presence in the blood.

3d, In the case of some morbid secretions depending on the organ, a simple relation may be observed between the intensity of alteration in the blood, and in the secreted fluid.

Dr. Christison first discovered that in renal dropsy, the albumen diminished in the serum in proportion as it increased in the urine. I have had one opportunity of verifying his observation.

J. Mackenzie, admitted to Dr. Christison's clinical ward, Royal Infirmary, Edinburgh,—renal dropsy.

January 29, 1838. Serum, sp. gr. 1·0238, contained a considerable amount of urea.

January 30. Serum, sp. gr. 1·025. Less urea.

February. .... 1·027

February 8. .... 1·0275

At this time he was much improved; the blood and urine afforded the following analysis:

Blood.

Water	825·2
Hematosine	95·5
Fibrin and nuclein	4·3
Albumen	67·3
Salts	4·2
Urea and lactates	1·9
Seroline and oil	1·6
	1000·0

Urine passed at noon, sp. gr. 1·011.

Water	979·4
Urea	9·7
Salts	7·7
Albumen	3·2
	1000·0

During the above period the urine was carefully examined by Dr. Edwin Adolphus, then clinical clerk, who found its specific gravity to increase generally, while less albumen was thrown down by boiling.

From these circumstances we can readily perceive how important is the due performance of secretion to the preservation of a healthy constitution of the blood. We have now to consider the natural history of the proximate elements of blood.

Water. This universal constituent of animal and vegetable bodies is received into the system by drinking, and absorption from the skin. The latter subject is fully discussed in Dr. Madden's late essay on Cutaneous Absorption, Edinburgh, 1837. According to Sir Charles Bell, water is principally absorbed by the large intestines, the small being employed in the introduction of chyle to the system. The kidneys, lungs, and skin are the principal emunctories of this fluid; next come the liver and lacrymal gland. We have reason to believe that the system is very sensitive to an irregular amount of water in the blood, for a draught of water is soon followed by the call to void urine; and the balance between perspiration and the liquid ingesta is often maintained with little assistance from the kidney. In one case, no urine was passed for thirty hours, by an individual drinking copiously under an attack of sea sickness. On another occasion, a few ounces of high-coloured urine were passed after ten hours' exertion in hot weather, though about two gallons of cold spring water were taken during that time. Of all principles of blood this is the most readily replaced by absorption.

Hematosine. Our knowledge of this substance is as yet very incomplete. Our first and last acquaintance with it is in its perfect state, for we saw before that the red tint of the chyle is merely owing to hematosine absorbed by lymphatics. And as we do not know of any further purposes which it serves beyond the circulation, so we have reason to believe that it is intended to be somewhat of a fixture in the system, its loss being supplied with difficulty. With the view of ascertaining the comparative facility with which these principles are renewed, the following case was selected. A middle-aged woman, affected with chronic bronchitis, was bled repeatedly at short intervals, with the view of relieving general oppression. On one of these occasions I obtained the blood, which was thus constituted:

Water . .	829·9
Fibrin and nuclein .	6·3
Hematosine . .	45·6
Albumen and salts .	118·2
	1000·0

From this and other observations, I conclude that hematosine is the most difficult to be replaced of all the elements of the blood. To apply this practically :—

A severe attack of sea-sickness, though it may reduce a man to a shadow, seldom produces lasting inconvenience ; in almost all cases a good appetite and active stomach restore the bulk and vigour of the system in a surprisingly short space of time. In cholera, the introduction of saline solutions into the veins suddenly restores for a time the animation and even spirits of the patient. But in cases of severe inflammation, as of the lungs, when 140 ounces of blood have been occasionally drawn, we know how long such patients require to recover strength, especially their colour and animal temperature. Yet all this is accomplished readily by the transfusion of blood from another individual, and as before shewn, the fibrin is not concerned in this vivifying influence. In sea-sickness and cholera, the red globules are not diminished in quantity, and the other parts of the blood are readily replaced. Hence we learn to substitute other means of depletion for venesection in cases where we apprehend difficulty in the restoration of strength during convalescence.

The connection of hematosine with the catamenia, has been already mentioned. This principle is formed in the system after removal of the spleen.

Fibrin. This principle first appears in the chyle and lymph. In the latter, it is probably the result of previous deposition. In both sets of vessels it seems to be formed from albumen during its passage through them, under the influence of general vital tendencies. Fibrin is not concerned in secretion in health; its destination is nutrition, excepting in inflammation, where it is copiously effused. From the hexagonal appearance of this principle in pericarditis, &c.,

it appears as if originally effused in the form of liquor sanguinis, the contraction from which state produces the figure first mentioned, as observed in cooled basalt, &c. It is probably formed with facility in the system, both from the last mentioned analysis, and because it is found undiminished in last-drawn blood, as I have endeavoured to prove in a former chapter. P. 39.

Albumen. This substance is perhaps the most important element yet known in organic chemistry. It is the only one apparently contained in mesenteric chyle, with the exception of salts and the like; consequently both fibrin and hematosine are probably formed from it. Chyle contains much albumen in a peculiar form, to which Dr. Prout has given the name of incipient albumen; it is not thrown down by boiling, until the addition of acetic acid, after which an abundant precipitate is obtained. It may be similar to the albuminate of soda of Lecanu and others. From this circumstance, as well as that observed by Tiedemann and Gmelin, that more albumen is found in the chyme of dogs fed upon hard-boiled eggs, than those in a raw state, it is probable that this principle is formed by vital influence, and not directly absorbed from the food. Besides, were it not so, it is difficult to see how albumen should be produced from our food in cases, if any such occur, where it contains none.

But Prout and Marcet state, that they found more albumen in the chyme of dogs fed upon animal than upon vegetable food; and the German physiologists found the albumen in the crop of birds to correspond with the animal or vegetable food on which they had been fed.

The use of albumen, and its importance in the system are evident, especially when we reflect that it does not enter into the composition of any fluid strictly excrementitious, and the urine does not include it among its numerous healthy constituents.

Salts.—These substances, though contained in the blood in minute quantity, perform many important offices: their effect on the colour of blood has been already noticed, as well as the circumstance that they supply acid and alkali to the

secreting organs. This is not the place to describe the so-called galvanic relations of the stomach and liver, the serous membranes, and the skin: they present an interesting field for speculation and research. Salts are found in every solid and fluid of our body, and appear indispensable to animal life.

Lactic Acid.—Berzelius, the discoverer of this acid, states, that it is a general product of animal decomposition, even within the body. He considers it as generated by the muscles, neutralized in the blood, and carried off by the kidneys. The acid theory of some German physiologists has been already alluded to.

Iron.—Emmert says, this metal may be detected in the chyle, by first adding nitric acid, and then tincture of galls. It is therefore less intimately combined than in the blood. Oehlenschläger has found iron in the blood of puppies before sucking. The iron is found in minute quantity in the bile, and probably in the menstrual evacuation.

Fat.—Oily matters are found in chyle, from whence they readily enter the blood. It is deposited in the cellular membrane, and appears to be the only element of our system which may accumulate to an almost unlimited extent in it. It is liable to a species of hypertrophy, of which Daniel Lambert has furnished us with a memorable instance.

The nature of our present inquiry confines us to the use of fat in relation to the blood. And as most theories of its use hitherto proposed have not proved very satisfactory, I am diffident in offering what I believe to be a novel hypothesis on the subject. Of the four elements of organic principles, oxygen and nitrogen are contained in air, and hydrogen and carbon, with a little oxygen, in fat. So fat is complementary to air, or in other words, fat and air together furnish materials for all our tissues. Consequently, as long as fat can be supplied, so as to be introduced into the blood, we can hardly perish for want of nourishment. If so, nature, in laying up stores of fat, has taken the most effectual means for providing against the evil day. To this it may be objected, that the

evolution and absorption of nitrogen are generally equal, as well as the volumes of oxygen absorbed, and of carbonic acid evolved. But it may be answered with equal truth that, generally speaking, absorption and deposition of fat are equal, and almost certainly so in the few instances where the gaseous products of respiration have been measured. It remains to be shewn, whether a fat animal, undergoing starvation, returns the full amount of inspired air; and whether or not an excess is exhaled when much food is accompanied by deficient exercise. We know the influence of exercise in reducing fat; does this depend upon the increased respiration accompanying it?

There are two more principles belonging to blood, which sometimes accumulate in disease—urea and sugar.

Urea.—This interesting substance can only be considered here in relation to the blood, and the following points must be briefly discussed. What proofs have we of its presence in healthy blood? Whence does it derive its origin? and to what amount does it exist in the system in health and disease?

1st, Does urea exist in healthy blood. Mr. Macgregor of Glasgow has failed to detect it there, though several pounds of serum were employed in the experiment. In cases of diabetes mellitus, rheumatism, and typhus, I was not more successful. But the question is answered affirmatively by the celebrated experiment of Prevost and Dumas, who obtained 20 gr. of urea from 5 oz. of blood from a dog, whose kidneys had been excised. Two ounces of cat's blood yielded 10 grains. Vauquelin and Segalas have confirmed the discovery.

2d, What is the source of urea? There seems reason to adopt the view that urea is formed in the blood, principally from materials previously existing in it. We shall soon have occasion to observe that urea is eliminated by the kidney to the amount of upwards of 300 grains daily. As, moreover, so large a secretion as that of the kidney is abundantly impregnated with it, the chyle, which cannot greatly exceed it in

quantity, should, if it be the channel of its introduction, exhibit most decided evidence of its presence: this has not been obtained.

It is almost certain that the materials of blood newly incorporated with the mass, give rise to urea, by some process which they undergo. Nysten examined the *urina chyli* and *urina potûs*, and found the solids of the former to exceed those of the latter in the following proportion:

Urea	.	.	13 : 1
Salts	.	.	4 : 1
Uric acid	.	.	16 : 1

This leads us to believe that urea is secreted in increased quantity after a meal.

But the greater part is independent of food, for Lassaigne found it in the urine of a madman who had fasted 18 days, and it is contained in the urine of reptiles who have fasted for months.

It is probably formed in one of these methods. In the vinous fermentation, carbonic acid is given off by sugar during its conversion into alcohol, because three atoms of sugar are equivalent to one of alcohol and one of carbonic acid, or, the latter is complementary to the change thus effected. In the same manner, urea may be complementary to certain changes going on in the blood, and the more thorough animalization of certain principles. It may be complementary to the formation of fat, which contains no nitrogen, or to that of bile, fibrin, &c.

It is barely possible that cyanic acid, like purpuric, may be formed, which uniting with ammonia, gives rise to urea. It may be produced during the act of respiration, though our analyses have not detected it in arterial blood. It may be a result of venization; in either case it should accumulate to a certain degree, because but a small portion of the blood can be transmitted through the kidneys at each circulation.

3d, To what amount does urea exist in the renal secretion in health and disease?

Much error has prevailed upon this subject, and a good deal has been said about conversion of urea into sugar, toge-

ther with sundry ingenious comparisons of the ultimate analysis of these principles. The annexed table will shew that the data upon which these calculations are founded have been hastily laid down. In my own experiments I have imitated Macgregor's process for getting urea from diabetic urine, by fermenting out the sugar by yeast. That gentleman has fixed the average amount of urea at about 360 grains daily, and in one case of *inversio vesicæ* he obtained 428 grains. Some analyses made by myself go to corroborate the accuracy of this statement. The amount in disease has been found as below :

Disease.	Daily Urea.	Observer.
Diabetes mellitus	1013· grains.	Macgregor.
—	945·	—
—	810·	—
—	512·	—
—	667·	The Author.
Diabetes insipidus	310·	Macgregor.
—	400·	—
— (26 lb. of urine daily)	336·	The Author.
Renal dropsy	332·	Macgregor.
—	180·	—
—	274·	—
Jaundice	217·	—
—	325·	—
—	315·	—

In some cases I have confirmed the observation of Professor Christison, that diabetic urine will frequently crystallize on the addition of nitric acid, after evaporation to one-eighth of its bulk.

I could find no urea in the blood of a patient labouring under delirium, in a well-marked case of typhus fever.

Sugar. The history of this substance in the system is now tolerably complete. It was formerly thought to be formed by the kidneys, but we have abundant evidence of its systemic origin. Wollaston and Marcet denied its presence in the blood, and this opinion was maintained generally till 1836, when Ambrosiani of Milan obtained it in crystals, as well as a

syrup which fermented with yeast. Just before this fact was made known in England, I succeeded in obtaining sugar from a well-marked case of diabetes, at St George's Hospital, London, and published the circumstances in the Medical Gazette for March 5, 1836, not being at that time aware of Ambrosiani's experiments. Since that period the subject has been taken up in an admirable manner by M'Gregor of Glasgow, who traced the sugar from the stomach to the secretions. We can now furnish the following account of this principle:

Sugar is formed in the stomach of healthy individuals after a meal of vegetable food; but not after animal substances have been taken. It may be occasionally found in the blood of healthy individuals, though in very small quantities; at present it has not been detected in healthy urine.

In diabetes the same takes place, though to a much greater extent, and less in dependence upon the quality of the food. A diabetic patient being made to vomit, and fed upon roast beef and water for three days, was again subjected to the action of the emetic, and the matter thus vomited fermented briskly when mixed with yeast. The experiment was repeated on the same and another patient, with similar results.

Sugar was also obtained from the saliva of diabetic persons, though not from their sweat. I have observed a distinct saccharine odour of a sickly description in the breath of such a patient—it was also observed by others. Yeast administered by M'Gregor to diabetic persons after a meal, had to be discontinued, because, to use their own expression, they were "on the eve of being blown up." He also procured sugar from the stools, when quite free from urine.

The amount of sugar passed in this disease is sometimes very great; I have seen it amount to 24 ounces daily, exclusive of salts and urea.

Perhaps an apology is scarcely needed for the frequency with which the limits of Physiology have been exceeded during the present Essay. As there are no such artificial divisions in nature, it were as well to carry them no further in our writings than may serve our convenience in the study or arrangement of a subject. For, as the primary sciences of botany, chemistry,

and anatomy, are as a basis to those more advanced, so do these last, as physiology, pathology, and therapeutics, afford a foundation to such others as surgery and practice of medicine. And being superimposed in this order of stratification, each may derive much assistance from those which stand higher in the scale, many facts belonging to medicine and surgery bearing upon anatomy, and still more upon physiology and therapeutics.

In this point of view, the study of medicine may be compared to the ascent of a mountain, whose widely extended base is crowned by a lofty and pointed summit. And as the traveller commencing a tedious ascent, gladly avails himself of such streams as descend from above, so may we, engaged in the pursuit of the more elementary, profit by such assistance as can be derived from other and more advanced branches of science.